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Courtesy Enka Plastics, Beverly Hills, Calif.

Plastic sailboat made of four plies Fiberglas #164 cloth, and Bakelite Corporation resin BRS 16631. The hull was made in one section. The top is made of wood. No pressure used in molding. A sunlight catalyst was used to cure the resin. Its speed is 15 per cent faster than a wooden boat.

LOW-PRESSURE LAMINATING *of* PLASTICS

by

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To

J. C. H.

9

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Preface

Many lessons in plastics were learned during the war years, and that knowledge is slowly trickling forth into the veins of industrial production. There have been published in the past many good books in the field of plastics, their manufacture, mold design, and related topics. So far, there has not been a convenient, usable compilation of the rudimentary information required for the beginner who wishes to embark upon the field of low-pressure and contact-pressure laminating of plastics.

This work proposes to outline the several steps necessary to fabricate a laminate, point out sources of materials required, and enumerate some of the pitfalls to be avoided. Some generalities are stated with the full knowledge that there are exceptions. The fundamental elements and guiding principles will be described so that to the novice, the field of plastics will appear neither as a hodge-podge nor as a final well organized fund of information.

The very young field of low-pressure laminating and fabricating has set forth in its swaddling clothes after V-J day to seek its proper place in the application to manufacturing problems and realize a share of world markets which no other form of plastics production can accomplish.

Constructive criticism and suggestions are invited by the author. The more widely and freely information is exchanged and published, the more rapid will be the advance by all engaged in this fascinating field of endeavor.

J. S. Hicks

Toledo, Ohio
November 1, 1946

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Acknowledgment

Thanks are due many of the firms listed throughout this book for supplying information.

Particular mention should be made for permission to use certain copyrighted material from the following: Bakelite Corporation, 300 Madison Avenue, New York 17, New York; Columbian Rope Company, Auburn, New York; and Huebner Publications, 2460 Fairmount Boulevard, Cleveland 6, Ohio.

Where information has been available, individual credit has been given for a number of photographs. Especially helpful has been the permission by W. R. Northlich, Director of Advertising, to use photographs from the files of Owens-Corning Fiberglas Corporation. Most of the photographs used without individual credit lines have been supplied from Mr. Northlich's files.

Finally, I offer my appreciation to Mary Wolever, who typed the manuscript and its revisions.

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Contents

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Chapter 1
The General Field of Plastics

Classification

When he asks what is meant by the term *plastics*, the inquirer is likely to receive as many answers as there are individuals in the party. We think of a plastic material as something that can be shaped or molded, perhaps with the aid of heat or pressure, or both. In general that is correct.

In the large field of resins there is a convenient classification into two groups: the *thermoplastic* resins, which are of such a nature that they soften when heated, harden when cooled, and may again be softened when heated. The second group are the *thermosetting* resins, which first soften when heated, and then harden when heated for a certain time at a certain temperature, after which they do not soften appreciably when again heated. This process of hardening the thermosetting resins is known as the *curing cycle*.

Following is a partial list of resins and their trade names according to this classification:

Chemical Name	*Trade Name*
	THERMOPLASTIC
Acrylics	Lucite, Plexiglas
Casein	Ameroid
Cellulose acetate	Chemaco, Fibestos, Kodapak, Lumarith, Nixonite, Plastacele, Tenite I, Vuepak
Cellulose acetate butyrate	Tenite II
Cellulose nitrate	Celluloid, Nitron, Nixonoid, Pyralin
Cellulose propionate	Forticel
Ethylcellulose	Ethocel, Ethofoil, Lumarith E.C., Nixon E.C.
Polyamide	Nylon
Polystyrene	Bakelite, Cerex, Loalin, Lustron, Polyflex, Styraloy, Styramic, Styron
Vinyl	Geon, Saran, Vinylite

Chemical Name	*Trade Name*
	THERMOSETTING
Allyl alcohol	Allymer, Kriston, MR Resins
Melamine	Melmac, Plaskon, Resimene
Phenolic (cast)	Bakelite, Catalin, Marblette, Prystal
Phenolic (molded)	Bakelite, Durez, Durite, Heresite, Indur, Insurok, Makalot, Resinox
Polyesters	Bakelite, Laminac, Selectron, Thalids
Urea	Bakelite, Beetle, Plaskon, Sylplast

Notes

1. Trade names of resins may be located on pages 1356–1371 of the 1946 "Modern Plastics Encyclopedia," published by Plastics Catalog Corp., 122 E. 42nd St., New York 17, N. Y. Thus the manufacturer of the plastic may be identified.
2. See "Plastics in Practice" by John Sasso and M. A. Brown, McGraw-Hill Book Co., New York, N. Y.
   Page 171: Reference catalogs on plastics indexed by companies.
   Page 175: Reference catalogs on plastics indexed by materials.

The terms *low pressure* and *high pressure* have been used very loosely. One classification is as follows:

High pressures: from about 500 psi up.
Low pressures: from about 75 psi to 500 psi.
Contact pressures: from about 0 to 75 psi (pounds per square inch).

In this book we shall take up a certain few of the thermosetting resins which may be used in the curing cycle at low pressures up to 100 pounds per square inch, with especial attention to the range of pressures of 0 to 15 pounds per square inch.

In the field of high-pressure laminating and fabrication it is not unusual to encounter molding or curing pressures of 1,000 to 8,000 pounds per square inch and temperatures of 270 to 340° F. In such processes, large, heavily constructed hydraulic presses are used in order to withstand the many tons of total pressure exerted. When the manufacturer turns to low-pressure resins, so called because they can be cured at low pressures, it is no longer necessary to use such heavy equipment. Low-pressure fabricating is also known by other terms, such as contact-pressure molding, fluid-pressure molding, flexible-pressure molding and impression molding. In fact, light-weight sheet metal molds may be used. These will be more fully described in the chapter on molds. Other forms

of molding, such as compression, transfer, injection and extrusion molding, are described in references cited at the end of this chapter.

The terminology in the field of plastics is in a state of flux. Some think of laminating plastics as comprising flat sheet forming only. In this book the title is intended to include the field which some call "molded laminates" or contoured parts as well as flat sheets, whether one ply of filler is used or several laminae of different reinforcing materials are used.

We have taken a brief glimpse of the wide field of resins, of which only a few in number of the thermosetting resins are adapted to the field of laminating at low pressures and contact pressures. These few will be described in detail in Chapter III.

The fundamentals of laminating a reinforced plastic flat sheet or a formed object involve only the two elements of a *resin* plus a *reinforcing agent*, combined and subjected to a curing cycle of heat and pressure to yield a reinforced plastic product.

The resins may be: contact resins, copolymers, thermosetting resins.

The reinforcing agents may be: asbestos, burlap, cotton, glass, linen, paper, rayon, sisal or wood.

The reinforced plastic products resulting may be: ailerons, aircraft parts, airplane floats, automotive parts, boats, bus parts, data cases, decorative panels, flooring, helicopter applications, jettison gas tanks for aircraft, luggage, phototemplate sheets, pilot seats, radio cabinets, radomes, terminal boxes.

The properties of a reinforced plastic depend on the individual characteristics of both the resin and the reinforcing agent plus any new, additional or modified properties resulting from the curing step of the combination.

The resistance to chemical solutions and other chemical properties are very important; and so are the tensile strength and other physical properties. The end use for the reinforced plastic and the limitations of laminating technique suggest the combination of materials to be used. The economic features of the problem must also be weighed. These are discussed in Chapter VI.

Post-Forming

Since the subject of *post-forming* is rather new as it is applied to low pressure-laminated plastics, we shall discuss it only briefly. It

should be pointed out that many of the cured thermosetting resins already mentioned do have thermoplastic or *thermoelastic properties* especially at higher temperatures such as 300° to 350° F. After flat sheets have been laminated and cured, they may be formed to special shapes by heating them and placing them in a cold mold. This is called post-forming. Both high-pressure sheets and low pressure-laminated sheets may be post-formed.

With such a new technique, the low cost of mass production of flat sheets of laminated plastics on continuous machines brings a new material to many work shops. Suppliers of laminated flat sheets include the following:

Continental Can Co., Cambridge, Ohio
Continental-Diamond Fibre Co., Newark, Delaware
Formica Insulation Co., 4614 Spring Grove, Cincinnati, Ohio
Haskelite Mfg. Corp., 701 Ann St., N.W., Grand Rapids, Mich.
Mica Insulator Co., Schenectady, N. Y.
Shellmar Products Co., Mt. Vernon, Ohio
Swedlow Plastics Co., 5531 South Riverside Dr., Los Angeles, California
Synthane Corp., Oaks, Pa.
U. S. Plywood Corp., 55 W. 44th St., New York 14, N. Y.
U. S. Rubber Co., Mishawaka, Indiana.
Western Products, Inc., Newark, Ohio

It should be mentioned here that flat sheet laminating is not a complicated process. Continuous machines may run at speeds of 25 to 100 linear feet or more per minute. Figure 1 shows a diagram of contact-pressure laminating of Fiberglas. It has been suggested that such flat sheet laminates may be made continuously on a machine set in a vertical position for the coating and curing steps. Thus gravity would help "flow" the resin and would also tend to hold the plies together during curing, contrary to the horizontal type of machine.

The forming procedure involves simple operations. The flat sheet is heated at or above its curing temperature uniformly from *both* sides, as in an oven, to just the right temperature in order to soften the laminate. Various methods of heating can be used, such as gas or electrically heated ovens, infrared lamps, parallel hot plates, and the like. A very rapid method of heating is to immerse the sheet in hot oil or molten alloys at a temperature of 485-

500° F. Care must be taken to avoid overheating, which may result in blistering of the resin or in its becoming brittle.

One shop uses a conveyor belt about 10 ft. long to move the $\frac{1}{16}''$ to $\frac{1}{8}''$ thick flat sheet laminate between two "banks" of

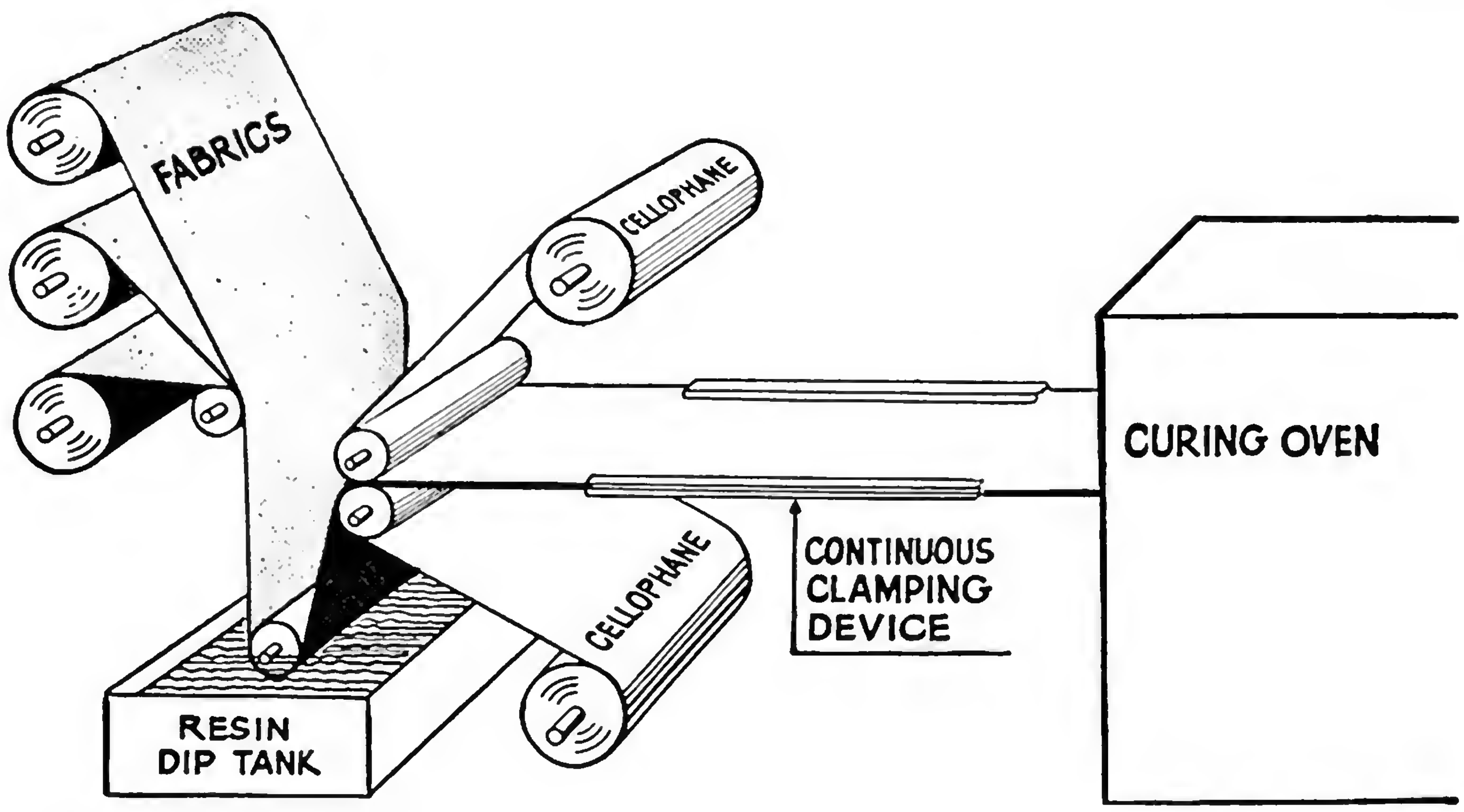
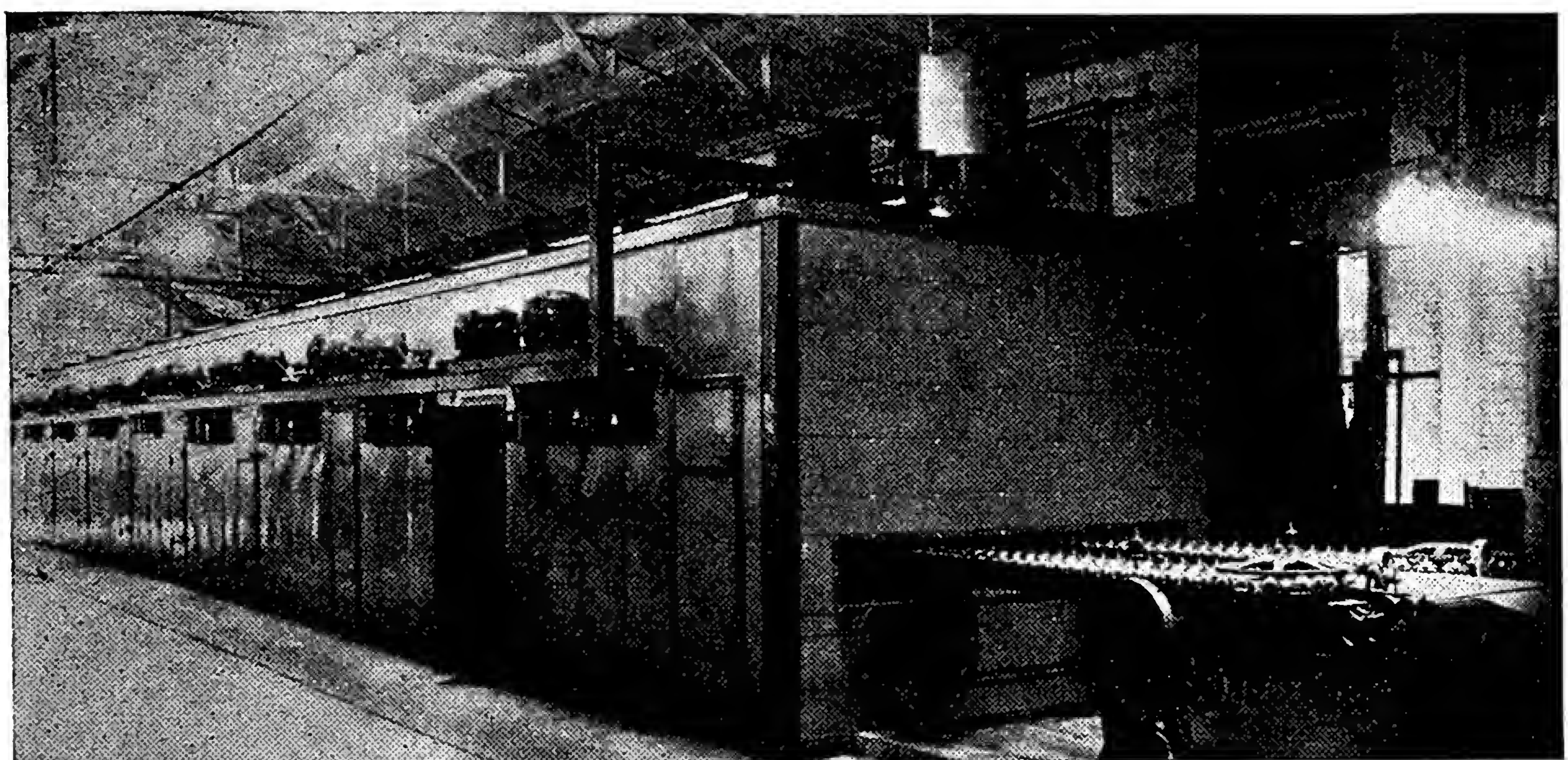


FIGURE 1. Diagram of contact pressure laminating of Fiberglas.



Courtesy National Drying Mach. Co., Philadelphia, Penna.

FIGURE 2. Tenter installation used for the curing of resins applied to fabrics. High air circulation assures uniformity of temperature for the producton of continuous flat sheet laminates.

infra red lamps. Heating of the laminate to a suitable postforming temperature requires about 20 seconds. The flat sheet (cut or punched as necessary) is placed in the mold to be formed into a box used by bakeries to deliver bread and other products.

Forming tools can be made from hardened plaster, plastics, metal

alloys, steel or hard wood. Pressures of 10 to 100 psi can be applied by screw clamps, toggle or hydraulic presses to the degree necessary. One-, two- and three-stage press dies may be used. The form may be left to cool in the mold for one or two minutes, depending on the prevailing conditions and requirements.

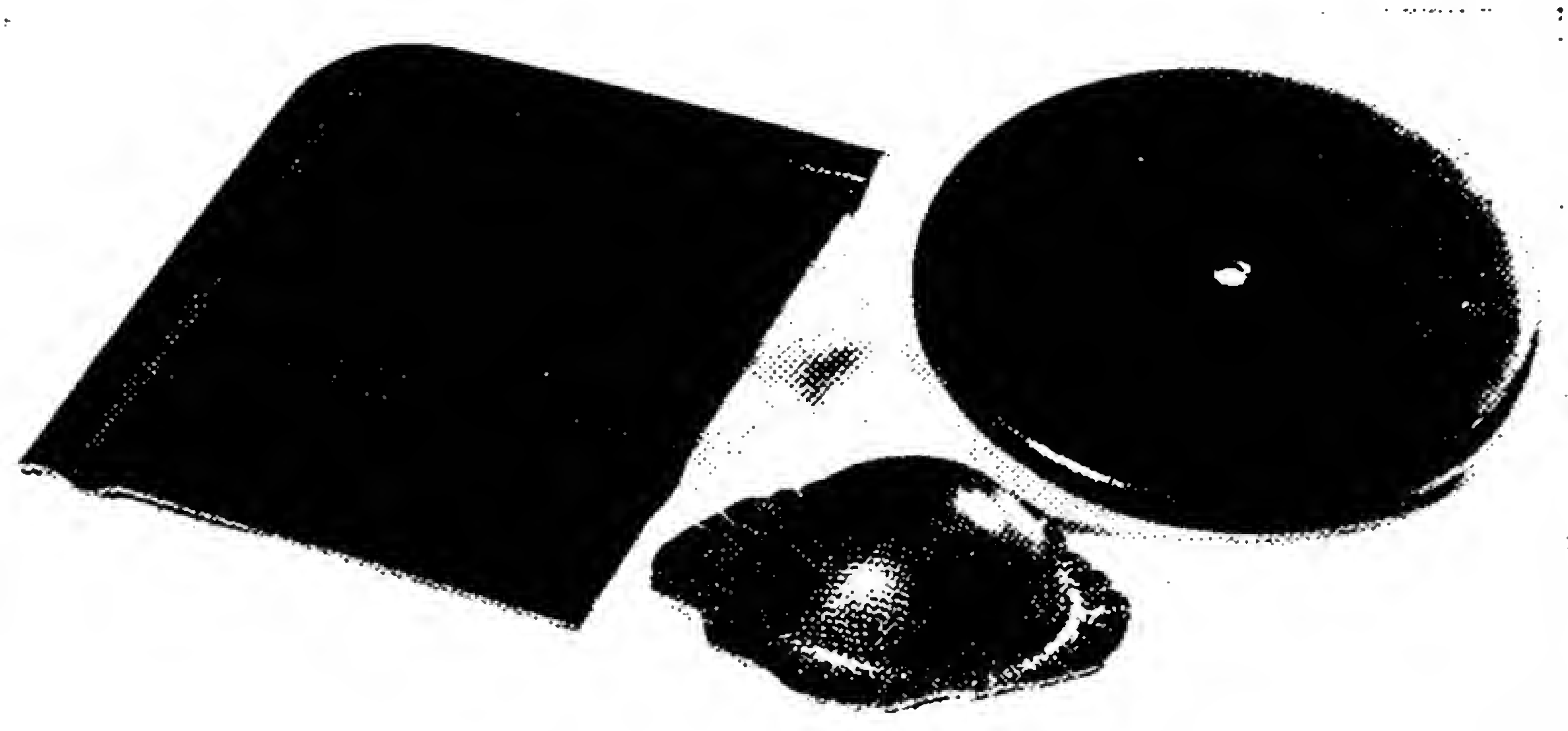
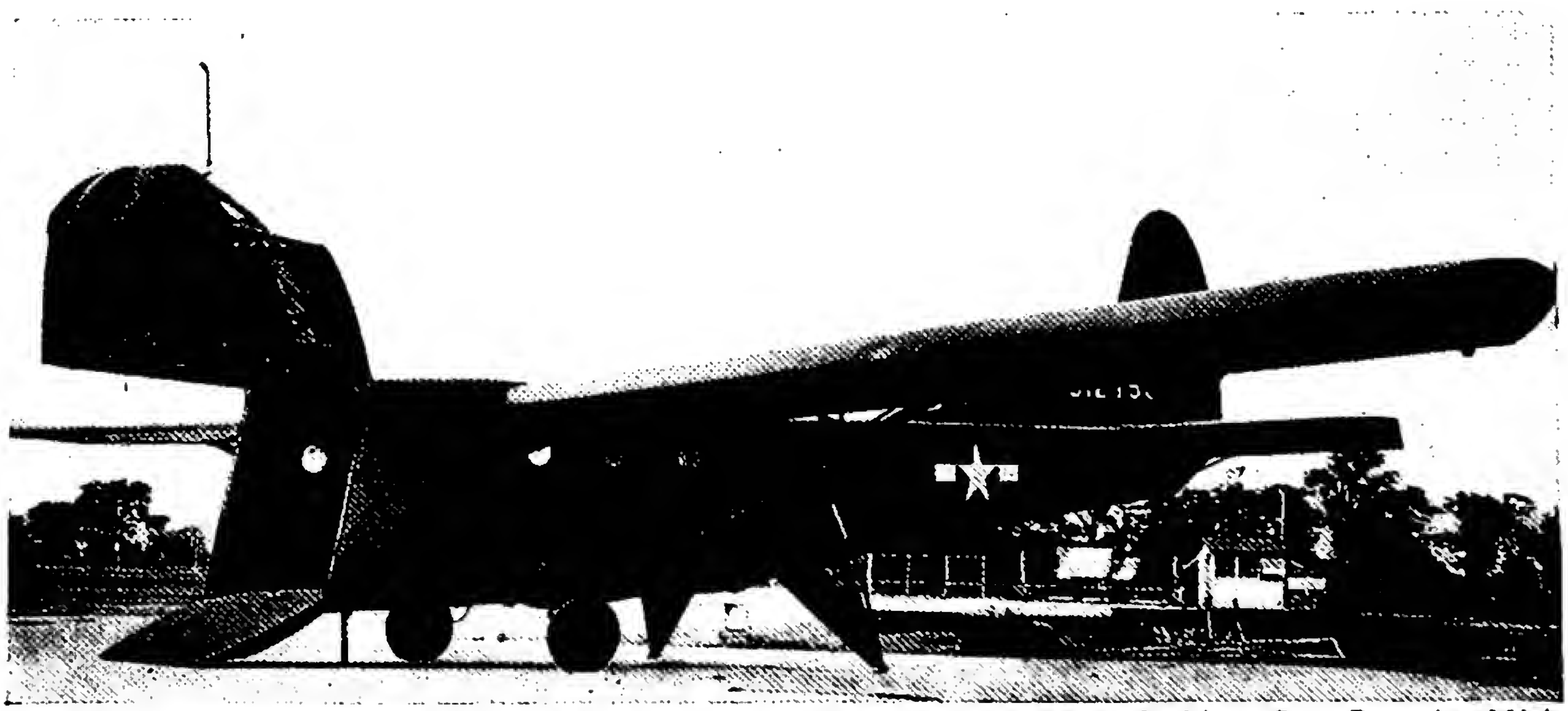


FIGURE 3. Parts which have been post-formed from flat sheets.



Courtesy Paramount Rubber Co., Detroit, Mich.

FIGURE 3A. CG-15 glider nose section.

The limits of the depth of draw and inside radius of bending depend on the nature of the resin, the reinforcing material and thickness of laminate being post-formed. The resin has some thermoelastic properties which permit drawing or stretching. Cotton cloth phenolics may be elongated 10 to 12 per cent lengthwise

and crosswise, and as much as 25 to 40 per cent diagonally. The maximum draw of cotton duck is on the bias. Eight-shaft satin weaves of glass cloth have a very limited draw; square-woven glass cloth permits greater draws; and a knitted glass cloth permits the greatest extensibility.

The heating cycle may require 30 seconds for $\frac{1}{32}''$ laminate to 3 minutes for $\frac{3}{8}''$ laminate to reach the forming condition. Thin sheets such as $\frac{1}{32}''$ to $\frac{1}{16}''$ may be bent on a short radius of $\frac{1}{8}''$, while thick sheets ($\frac{1}{4}''$ to $\frac{1}{2}''$) require a greater radius of bend, such as 1″ to $1\frac{1}{2}''$. The minimum-bend radius is in general equal to twice the thickness of the laminate.

The use of post-forming laminated plastics permits designers and manufacturers to use a new material. In many cases ordinary sheet steel or aluminum may be shaped into more varied contours or subjected to deeper draws, but new properties of reinforced plastics may now be added. Attempts to use undercured sheets have proved to be unsatisfactory because of delaminating characteristics and questionable physical characteristics.

Reference

"Postforming Methods and Applications" by W. I. Beach, *Modern Plastics*, page 142 (1946).

The subject of lamination of plywood will not be discussed in detail in this work because much has been written already on that topic, and furthermore pressures used in its fabrication usually exceed 100 psi. Often cloth is laminated to plywood, as in the case of noses of gliders, to give added impact strength.

General References

Books

"Experimental Plastics and Synthetic Resins," by G. F. D'Alelio, John Wiley & Sons, Inc., New York, 1946.

"Handbook of Plastics," by Herbert R. Simonds and Carleton Ellis, D. Van Nostrand Co., Inc., New York, 1943.

"Industrial Plastics," by Herbert R. Simonds, Pitman Publishing Corp., New York, 1945.

"Injection Molding of Plastics," by Islyn Thomas, Reinhold Publishing Corporation, New York, 1947.

"Modern Plastics," by Harry Barron, John Wiley & Sons, Inc., New York, 1945.

"Modern Plastics Encyclopedia," Plastics Catalog Corp., New York. Note especially the bibliography on page 1269.

"Plastics," by J. H. DuBois, American Technical Society, Chicago, 1945.

"Plastics and Industrial Design," by John Gloag, George Allen & Unwin Ltd., London, England, 1945.

"Plastics for Industrial Use," by John Sasso, McGraw-Hill Book Co., New York, 1942.

"Plastics Handbook for Product Engineers," by John Sasso, McGraw-Hill Book Co., New York, 1946.

"Plastics in Practice," by John Sasso and M. A. Brown, Jr., McGraw-Hill Book Co., Inc., New York, 1945.

"Plastics Mold Engineering," by J. H. DuBois and W. I. Pribble, American Technical Society, Chicago, 1946.

"Plastic Molding and Plant Management," by D. A. Dearle, Chemical Publishing Co., Inc., Brooklyn, 1944.

"Plastics Problems and Processes," by D. E. Mansperger and C. W. Pepper, Second Edition, International Textbook Co., Scranton, Pa., 1944.

"Plastics, Scientific and Technological," by H. R. Fleck, Chemical Publishing Co., Inc., Brooklyn, 1945.

"Special Reports on Plastics," Library of Industrial Research, Chicago.

"S.P.I. Hand Book," advance chapters 1 to 4 inclusive, The Society of the Plastics Industry, Inc., New York, 1945-1946.

"Technical Data on Plastics," Plastics Materials Manufacturers' Association, Washington, D. C.

"The Technology of Adhesives," by John Delmonte, Reinhold Publishing Corporation, New York, 1947.

"The Chemistry and Technology of Plastics," by R. Nauth, Reinhold Publishing Corporation, New York, 1947.

"The Chemistry of Commercial Plastics," by R. L. Wakeman, Reinhold Publishing Corporation, New York, 1947.

"The Chemistry of Synthetic Resins," by Carleton Ellis, Reinhold Publishing Corporation, New York, 1935.

"The New Plastics," by H. R. Simonds, M. H. Bigelow and J. V. Sherman, D. Van Nostrand Co., Inc., New York, 1945.

"The Plastics Buyer," 1945-1946 edition, Cleworth Publishing Co., Inc., New York.

"The Technology of Plastics and Resins," by J. P. Mason and J. F. Manning, D. Van Nostrand Co., Inc., New York, 1945.

"Thomas' Register of American Manufacturers" in which manufacturers are listed in a classification by products. Thomas Publishing Co., New York.

Magazines

British Plastics, Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.I., England.

Canadian Plastics, Toronto, Ontario, Canada.

Industrial Plastics, 2460 Fairmount Blvd., Cleveland 6, Ohio.

Modern Plastics, 122 East 42nd St., New York 17, N. Y.

Pacific Plastics Magazine, Miller Freeman Publishers, 124 W. 4th St., Los Angeles 13, California.

Plastics, 185 North Wabash Avenue, Chicago 1, Illinois.

Plastics and Resins, General Business Publications, 299 Madison Ave., New York 17, N. Y.

Plastics Reporter, 1214 Hyde Park Ave., Boston 36, Massachusetts.

Plastics World, 551 Fifth Ave., New York, N. Y.

Southern Plastics Magazine, 44½ Marietta St. Bldg., Atlanta 3, Georgia.

Chapter 2
The Design and Use of Molds

Plaster and Metal Molds

It has already been pointed out that expensive molds and heavy presses are not required by low-pressure laminating techniques. In the very familiar field of metal stamping in which dies are used, the tooling cost is very high, yet it is economical when many pieces are made therefrom, because the unit cost is low. However, when only a few dozen or a few hundred complicated shapes are to be made, the cost for tooling in order to use low-cost sheet steel may be prohibitively high. Consequently, the fabricator who knows his materials thinks of low-pressure laminating with reinforced plastics as the logical step.

One of the most economical materials suitable for use as a mold is plaster of paris. This product, as well as instructions for its use, may be obtained from:

U. S. Gypsum Co., 302 West Adams St., Chicago, Illinois.
National Gypsum Co., Burley Bldg., Delaware Ave., Buffalo, N. Y.

When a plaster mold has been made it should be dried thoroughly to a low moisture content. Oven-drying can shorten the time required from possibly days at the shop temperature to a matter of hours or probably overnight drying at 125 to 150° F. The thicker the mold, the longer time is required to dry it out. Failure to dry the mold initially may result in a damaged or uncured laminate later, after the curing cycle at an elevated temperature of say 180 to 275° F.

Various hardening agents are available to apply to the surface of a plaster mold. Usually these agents penetrate the plaster to a depth of 2 to 3 inches, and result in a much harder surface and more durable mold from which many more laminates can be made than from a mold not so treated.

The reader is referred to the following sources:

Duorite Plastics Industries, Culver City, California.

Furane Plastics & Chemical Co., 5233 W. San Fernando Rd., Los Angeles 26, California.

Palestic Inc., 316 N. Laflin St., Chicago 7, Illinois.

An excellent profusely illustrated booklet has been published by the Industrial Division of U. S. Gypsum Company. The title of this publication is "How to Make Patterns and Models with Gypsum Cement." Important items in its table of contents are as follows:

Period of Plasticity	Shop Layout
Reinforcements	Use of Template
Shop Equipment	Various Shapes

Reference

"Resins Give Plaster of Paris Improved Characteristics," by John Delmonte, *Plastics*, p. 38 (Oct., 1945).

A special plaster of paris-containing resin is known as "Hydromite" as supplied by the U. S. Gypsum Company. This material sets to a very hard and smooth surface which can be sanded without the need for a hardening agent. The manufacturer supplies complete instructions and technical data for its use.

Accurate cored plaster castings require templates and station locations to insure the proper position. Straight runs or contours can be made in plaster by mounting a female template so that one may slide it sideways over wet plaster along the edge of the work table surface. The reader is referred to a technical library for further details on working of plaster and related subjects.

The laminator may use a wooden mold. Much has been written on the art of pattern making. Large or small objects may be made from a pattern, usually constructed of hardwood and sanded down to a smooth finish. If a complete bag or envelope is used for the curing cycle, the wooden mold need not be braced so well nor constructed of an especially heavy material. If a single layer like a blanket is used during the curing cycle, it may be desirable to add suitable reinforcing members to the mold.

A sheet steel mold may be used, such as for fabricating an automobile hood or automobile fender. When such a sheet-metal mold is used, it is quite apparent that a laminate laid up on a metal

fender as a female mold will be slightly undersize as to dimensions, just as when used as a male mold, the laminate will be slightly oversize. Usually, in such a case, the reinforced plastic article can be fitted to the same location as the metal object because of two factors, *viz.*, the adjustable slot-type fastening holes, and secondly, the "give" or "springiness" of the plastic laminate.

At this point, attention is invited to the porosity of both plaster and wooden molds. When a low-pressure resin is heated during the curing cycle, the resin usually becomes very thin before it begins to gel and later harden. In the very thin condition or low viscosity, as it is called, the resin can and does penetrate even tiny holes in the mold. Therefore, it is usually desirable to use some filler or sealing material on a porous mold. Ordinary shellac has been used in many cases. Some special preparations are sold for that purpose. One supplier is:

Permaflex Mold Co., 710 East First Ave., Columbus 3, Ohio.

On plaster of paris molds, one may use three coats of clear lacquer as a sealer, drying thoroughly. Then apply a good coat of PVA solution (1 part PVA powder dissolved in 10 parts of water) by brushing, or dilute with water to spraying consistency (PVA denotes polyvinyl alcohol). Dry well at 110 to 120° F. Then apply a parting compound to the mold surface before laying up the laminate for cure.

Another suggestion for sealing plaster of paris molds has been offered by Dr. H. L. Gerhart of Pittsburgh Plate Glass Co. The dried plaster mold is soaked in Selectron #5001 for 15 min., then cured at 250° F plaster temperature. This results in a sealing to a depth of about 1/16" which appears to be adequate. The parting compound is then applied to the sealed surface before proceeding with the lay-up.

Other mold materials are aluminum castings and brass castings. Various factors enter into the selection of a suitable mold material. For one or only a very few pieces perhaps a plaster of paris mold is quite adequate. For higher-quality tooling of a more durable sort, anticipating the production of sizeable quantities of molded articles, one considers the metal molds. A bronze casting will also give long service. For a smoother finish on the surface of the

laminate it is often desirable to secure a smoother mold surface, such as polishing an aluminum casting, and chromium plating the sheet steel, brass or bronze molds. Reinforced concrete molds have also been used. For example, the nose for the glider shown in Figure 3a was molded on a reinforced concrete mold by Paramount Rubber Co., Detroit, Michigan. The plywood layers were reinforced by glass cloth for added impact strength.

Reference

"How to Resin Seal Porous Metal Castings" by P. C. Fuller, *Plastics,* May 1946, page 58.

A plastic-reinforced mold with good dimensional stability may be made using resin and Fiberglas. Other reinforcing agents may be used with a resin to make a mold.

Alloys may be cast to serve as molds. More information may be obtained from:

Belmont Smelting & Refining Works, 320 Belmont Ave., Brooklyn, N. Y.
Monarch Alloys Co., 503 North Chestnut St., Ravenna, Ohio.
Wayne Foundry Co., 3102 Hubbard St., Detroit, Mich.

Two alloys were widely used during the war as a male form on which to form glass reinforced plastic laminates. After the laminate has been cured, the alloy is melted out, as in a hot oil bath, and then re-cast for another molding. "Cerrobase" is a low-melting alloy of bismuth and lead with a melting point of 255° F. "Kirksite" is a trade name for a zinc-aluminum-copper alloy which melts about 720° F. Other low-melting alloys may be obtained from the suppliers just mentioned.

Sheet metal molds may be made of aluminum, copper (chromium or nickel plated), cold rolled steel, stainless steel or other materials suitable for the application intended. Some of the variables influencing the selection of the mold material are:

Simple or complex contours
Use of autoclave
Portable or fixed operation
Heat transfer speed required
Production requirements
Design of end product

A material called "Pattern Mold" has been developed expressly for making master patterns as used on duplicating machines in the die-making industry. This material has extreme hardness (as much as 20,000 psi) and a very low coefficient of expansion or shrinkage. It has been used successfully as a mold material on which to lay up reinforced plastics. "Pattern Mold" is supplied by:

W. B. Burke & Company, 1609 E. 36th St., Cleveland 14, Ohio.

The field of metallurgy and alloys is very extensive. Much information is directly applicable to mold making for low-pressure lamination of plastics. Some experience of the mold makers for high-pressure plastics can be used in this new field, but new problems have arisen because new techniques are being used. Other references appear throughout this book on molds and their use in the curing cycle.

Reference

"Engineering Alloys, Names, Properties and Uses," by N. E. Woldman and R. J. Metzler, American Society for Metals, 7016 Euclid Ave., Cleveland, Ohio.

Irrespective of the smoothness of the mold, resin will usually adhere to its surface unless a parting agent is used. A typical layout for a contact pressure laminate would be as follows:

(1) The mold of plaster, wood or metal.
(2) A sealer, if required.
(3) The parting agent.
(4) Laminate and resin to be cured.
(5) Cellophane sheet.
(6) "Bleeders" which are incorporated to prevent the sealing off of the rubber blanket. Unless bleeders are used it is difficult to secure a good vacuum to the entire surface.
(7) Bag or blanket (rubber or PVA sheeting).

Parting Agents

For Plaster, Wood or Metal Molds. When a plaster mold is to be made up from a wooden or metal form, a parting agent is desirable to insure good separation of the mold after the plaster has

"set" or hardened. A coating of the following composition has been found to be useful:

¼ lb. of stearic acid added to 1 gal. of Kerosene.

Other parting compounds or separating mediums for plaster are listed:

Petroleum jelly or vaseline
Lard oil
Light lubricating oil
Carnuba or bayberry wax
Soap
Camphor

Kerosene is a common solvent. Gasoline is more volatile and proper precautions should be taken when it is used as a solvent. Usually a thin coating of parting agent is sufficient.

For Resin Laminates Applied on Sealed Molds. If a Permaflex sealer is used on the mold, a graphite paste coating over the sealer will usually result in good parting of the laminate. One graphite preparation known as Renite paste FW, an oil-graphite mixture, is available from the Renite Company, Columbus, Ohio. Another parting compound for plaster of paris and wood molds filled with Permaflex which has been successfully used is called "Vejin."

For Resin Laminates Applied on Metal or Sealed Plaster or Wood Molds. In connection with the various types of molds for the formation of laminated plastics, various separating compounds or mold lubricants are used. Some of them are listed below:

(1) Carboxy methyl-cellulose
(2) Carnauba wax (other waxes)
(3) Cellophane
(4) Cellulose acetate
(5) Clearate-Lecithin (W. A. Cleary Corp., New Brunswick, N. J.)
(6) Glassine paper
(7) Graphite greases (Acheson Colloids Corp., Port Huron, Michigan)
(8) Moldeze (Protective Coatings Inc., Detroit 27, Michigan)
(9) "Ortholeum" 162 (E. I. du Pont de Nemours & Co., Inc. Petroleum Chemical Division, Wilmington 98, Delaware)
(10) P.V.A. sheet (Resistoflex Corp., Belleville, N. J.)
(11) 10% solution PVA in water with aerosol.

(12) Silicones (Dow Corning Fluid #200) DC pastes #4 or #7 (Dow-Corning Corp., Midland, Michigan)
(13) Stearic acid and stearates (barium, calcium, lead and zinc stearates (Witco Chemical Co., 295 Madison Ave., New York 17, N. Y.)
(14) Vejin A 3 (Vejin, Inc., Cincinnati, Ohio)
(15) Releasing Agent #595 (Polyplastex, Inc., 48-16 70th St., Woodside, New York, N. Y.)
(16) Petròleum jelly on polished aluminum molds.
(17) Selectron #5903, a non-film forming material resembling soap. Selectron #5905, a cellulosic film forming type. Supplied by Pittsburgh Plate Glass Co., Grant Bldg., Pittsburgh 19, Pa.

A parting compound found to be very useful on metal surfaces is Dow-Corning's Silicone DC-7 which should be used in a *very thin* coating. If this compound is used in a medium to heavy coating, it is likely to result in the incomplete cure of the resin used in the laminate. A cloth may be treated with a small quantity of DC-7 compound or Silicone fluid #200 and used to wipe the die or mold. For deep mold cavities and undercut areas a dilute solution of the parting compound is easy to apply. Silicone DC-7 may be dissolved in toluene to form a dilute solution and applied to the mold by spraying. As a guide to observe the complete coverage of the mold, color in the form of an oil-soluble dye may be added before spraying the mold.

A safe practice to follow is to experiment with mold release agents following the suggestions made by the supplier. Experimental initiative in one's own shop with its individual assortment of variables will soon determine the most successful parting compound to use and the best way to apply it. One may rub the parting agent on by hand, apply by brushing or by spraying or by wiping with a cloth. A dilute solution or very thin coating may be found sufficient when applied to the mold surface or rubber bag (or blanket) to last from 10 to 30 cycles of curing.

Other suggested solvents for silicones include benzene, carbon tetrachloride, xylene, gasoline, amyl alcohol, ethyl acetate and high-flash naphtha. Caution should be used with the more volatile solvents of an inflammable nature. Where solvents are objectionable, one may prepare an emulsion of silicone mold release fluid #200 in a concentration as low as $\frac{1}{4}$ of 1 per cent.

The silicone fluids have high flash and fire points, good oxidation resistance, very low vapor pressure, and a "low slope" for the viscosity-temperature curve. This means that the viscosity changes very little over wide temperature ranges.

Parting Agents Which Inhibit Cure. In some types of laminating, aluminum stearate and other compounds of stearic acid have been used as parting compounds. It has been found in connection with the cure of many contact-pressure resins that parting agents containing stearic acid often inhibit the cure of the laminate, and therefore should be avoided. For phenolic resins, stearates are satisfactory as parting agents.

Product and Mold Design Factors

The design of a mold as well as the properties of the material to be used depend on a number of factors. An analysis of the product contemplated for lamination should include consideration of the following points:

(1) How does the estimated cost in plastics compare with other materials such as cast metals or sheet metals?

(2) Do the advantages in plastics offset the economy of high production of metal parts?

(3) Check the design from the molding standpoint. Add design changes to facilitate molding in plastics; obtain change in specifications if required.

(4) Check tolerance limits. For metal the common tolerances are $\frac{1}{32}''$ fractional and 0.010″ decimal. Some resins shrink or expand in use, beyond the range of metal dimensional changes over a temperature gradient.

(5) Check compatibility of the mold material with type of resin to be used. For example, copper or brass inhibits the cure of some resins.

(6) Determine the type of resin to use and its physical and chemical properties, especially the mold shrinkage of the resin as well as the temperature coefficient of expansion of the mold. For example, a $\frac{5}{8}''$ bronze mold expands as much as a certain resin shrinks. In the case of another molding, the resin, upon cooling, shrunk $\frac{1}{8}''$ over a diameter of 18″, which was more than the contraction of the bronze mold. Adjustment in the mold design could correct this by adding $\frac{1}{8}''$ to mold size for each 18″.

The *mold design* should include consideration of the following factors:

(1) Rounded corners are desirable. Large radii for edges as well as for other contoured surfaces are desirable.

(2) If possible, use no undercuts. A 3° draft or more is preferable, depending upon the depth or length of the draw.

(3) Use diamond shape or other pattern for a mesh grill, not louvers as used in metal, for purposes of ventilation.

(4) Where vacuum is used, suitable channels should be provided. Include flutes or gates to allow entrapped air to escape.

(5) If inserts are to be molded in, a large bearing surface is desirable; for example, a flange section may be used.

(6) In prototype molding use trim lines for cutting dimensions. In production, build jigs for trimming to proper dimensions. In some cases a molded edge may require no machining operations, other than removal of resin flash.

(7) Prototype tooling may be designed to be adapted or used in later production. This is especially true when designs are not to be changed.

(8) A compressed-air connection may be included in the mold design to facilitate removal of the cured laminate.

(9) Decide the type of heating to be used for the molds. Suggested proven combinations are:

Mold Materials	*Heating System*
Any general material as wood, plaster or metal	Oven type
Kirksite alloy or cast aluminum or bronze	Strip heaters (electric)
Reinforced concrete with sheet aluminum liner (about 0.040″–0.060″ thick)	Steam-heating coils imbedded in the concrete structure. Caution: consider expansion of steam coils, *e.g.*, use thin-walled tubing to avoid breaking the mold.
Cast iron, chrome- or nickel-plated	Strip heaters or steam jacket
Copper liner, chrome-plated, over sheet steel mold	Steam jacket

The heat transfer or thermal conductivity of various materials which might be used for molds or which may be used for laminating flat sheets are as follows:

Material	*Btu per hr., per sq. ft., per °F, per foot thickness*
Copper	218
Aluminum	120
Zinc	64
Brass (70-30)	60
Nickel	34
Tin	34
Iron (wrought)	32
Steel	26
Chromium	25
Lead	20
Glass	0.6
Concrete	0.5
Plaster of Paris	0.4
Fiberglas plastic	0.3

Shrinkage. Shrinkage data on plastics are important in the design of molds because allowances must be made therefor. The material supplier can supply the data for various specified plastics or resins. Charts of data based on values such as .005″ shrinkage per inch may then be prepared in order to facilitate calculations for mold dimensions which will compensate for such resin shrinkage. Actual trial may then be necessary to check the possible additional effects of molding conditions and other variables when extremely close dimensional tolerances are required. Expansion allowances are provided for in a similar manner.

References

"Plastics Molds," by Gordon B. Thayer, third edition, Huebner Publications, Cleveland, 1946.

"Beryllium Copper as a Mold Material," by L. F. Boland, *Modern Plastics*, page 139 (February, 1946).

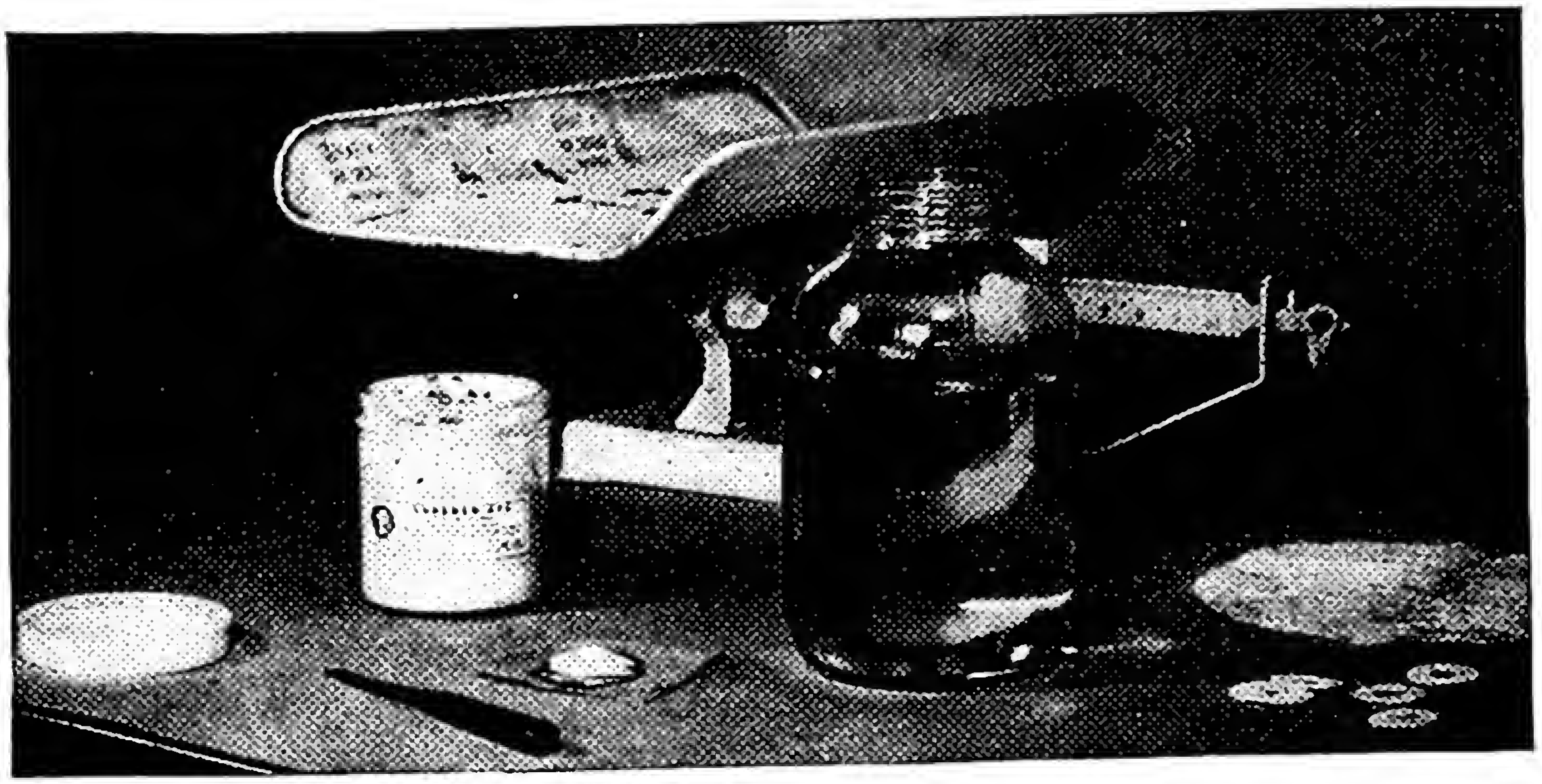


FIGURE 4.—Scales for weighing resin and catalyst.

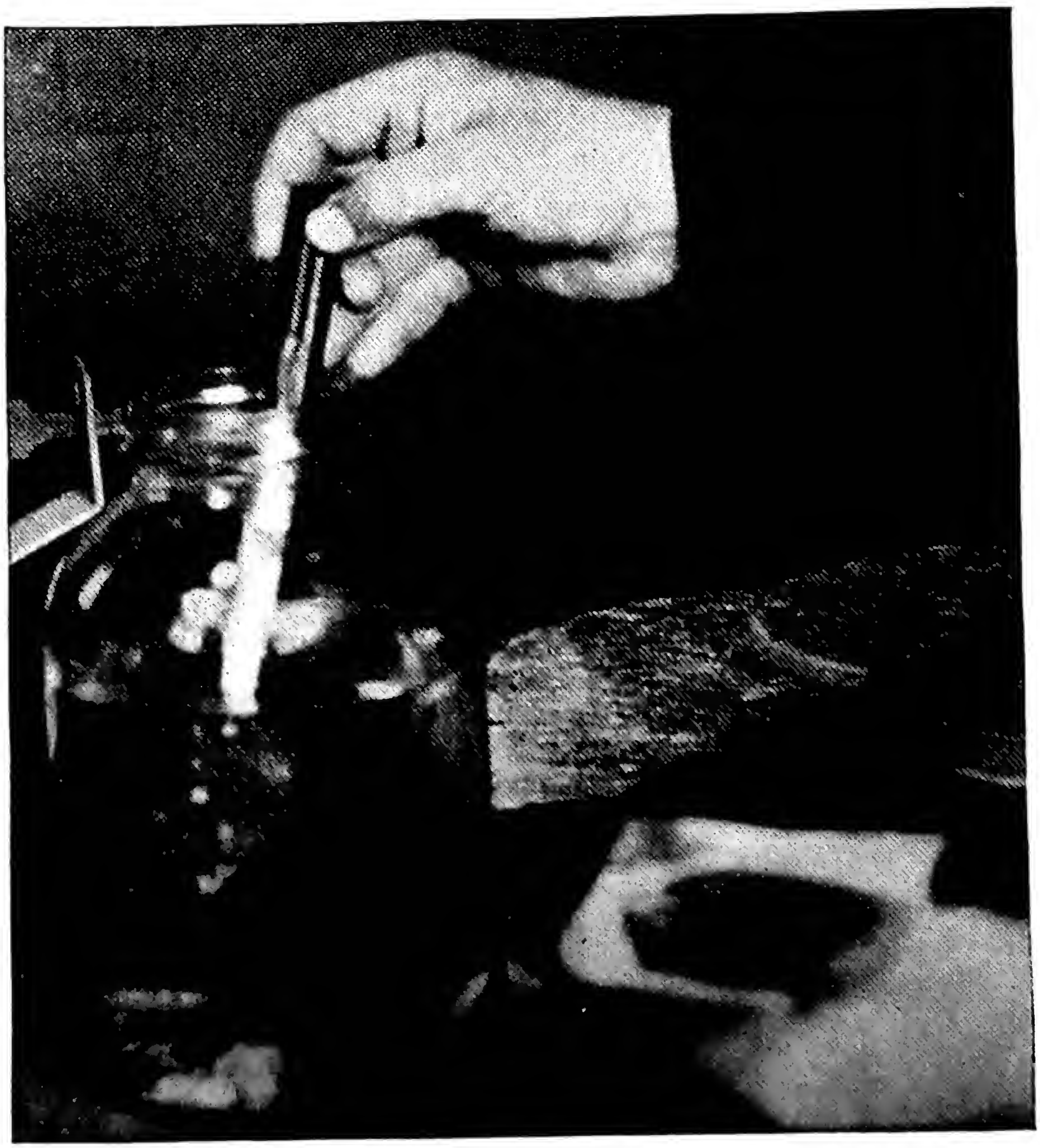


FIGURE 5. Stirring the catalyst into the resin.

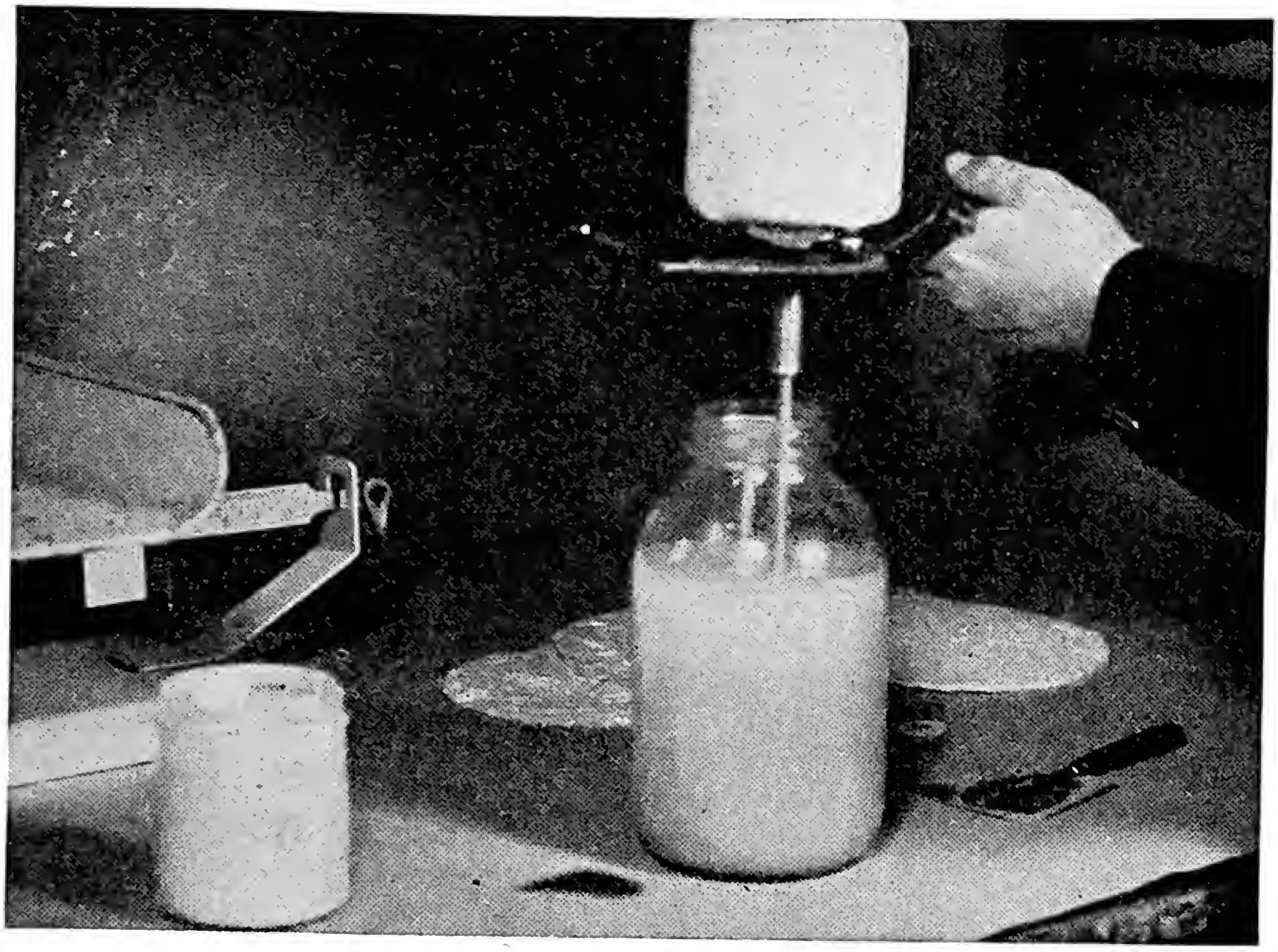


FIGURE 6. Thorough mixing of catalyst paste with the resin.

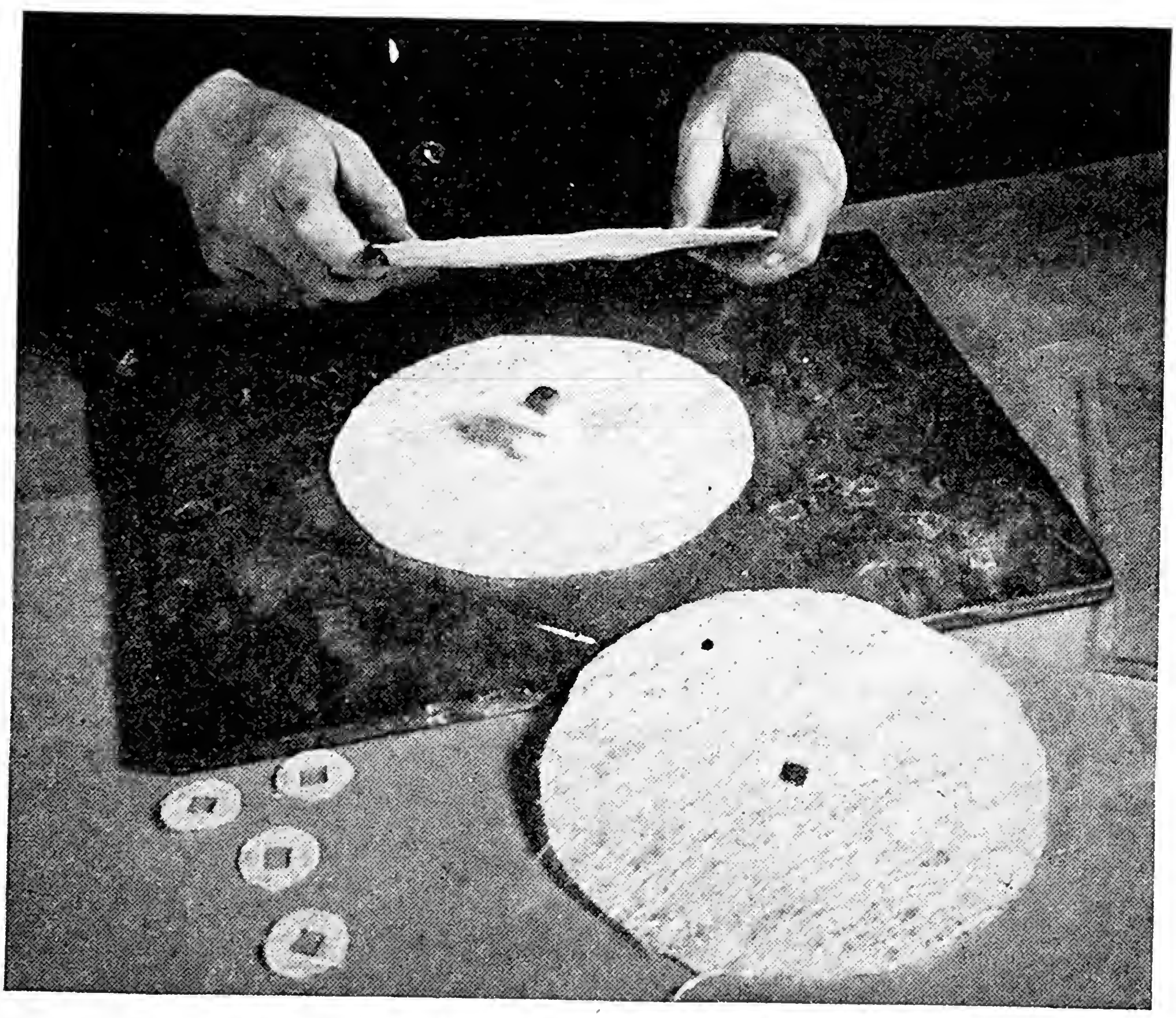


FIGURE 7. Placing discs of glass mat, previously cut out.

FIGURE 8. Pouring resin-catalyst solution on to the formed glass mat discs and reinforcing parts (small discs).

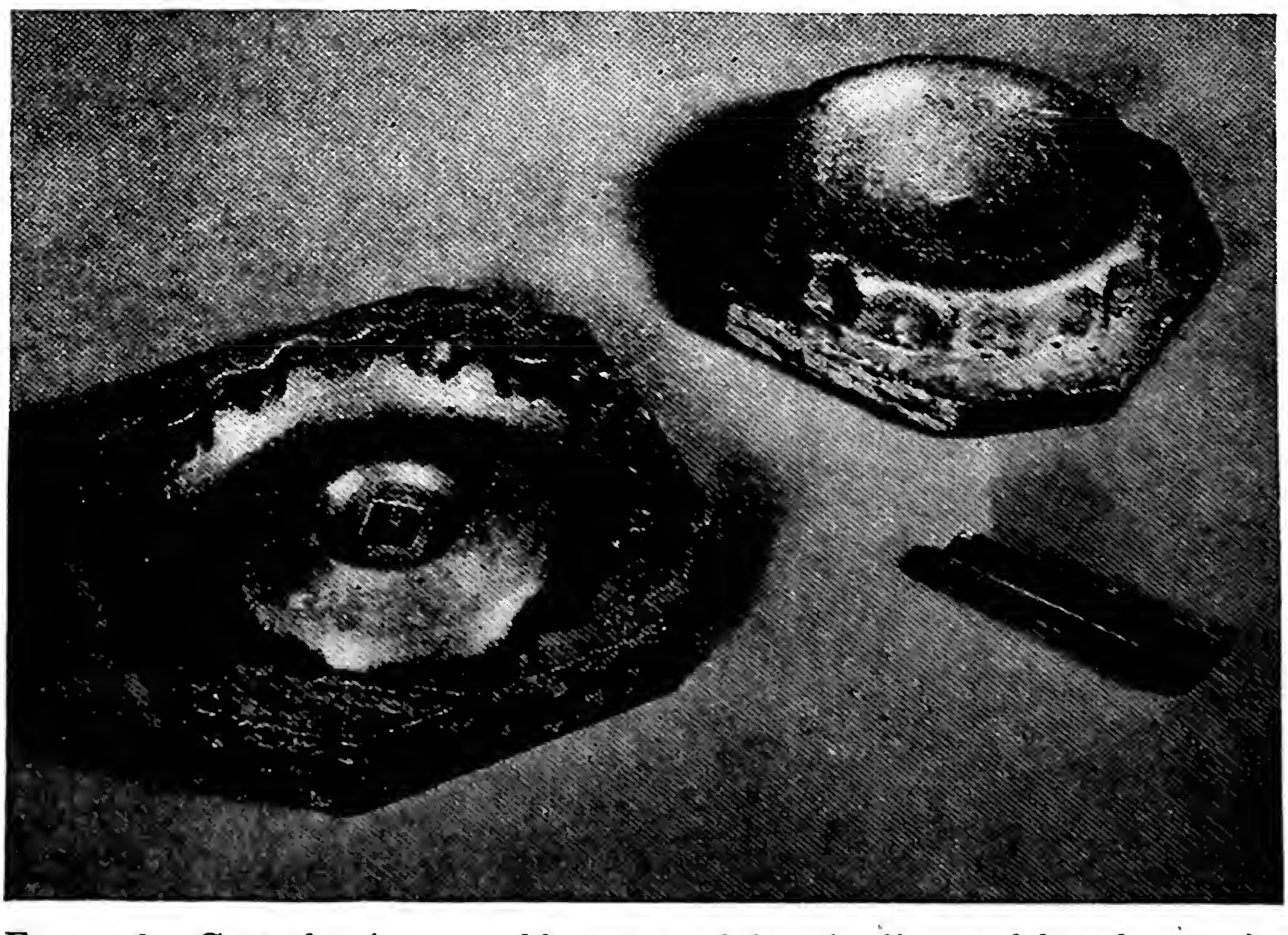


FIGURE 9. Cast aluminum mold, male and female dies, and knock-out pin. To be used for laminating a valve handle.

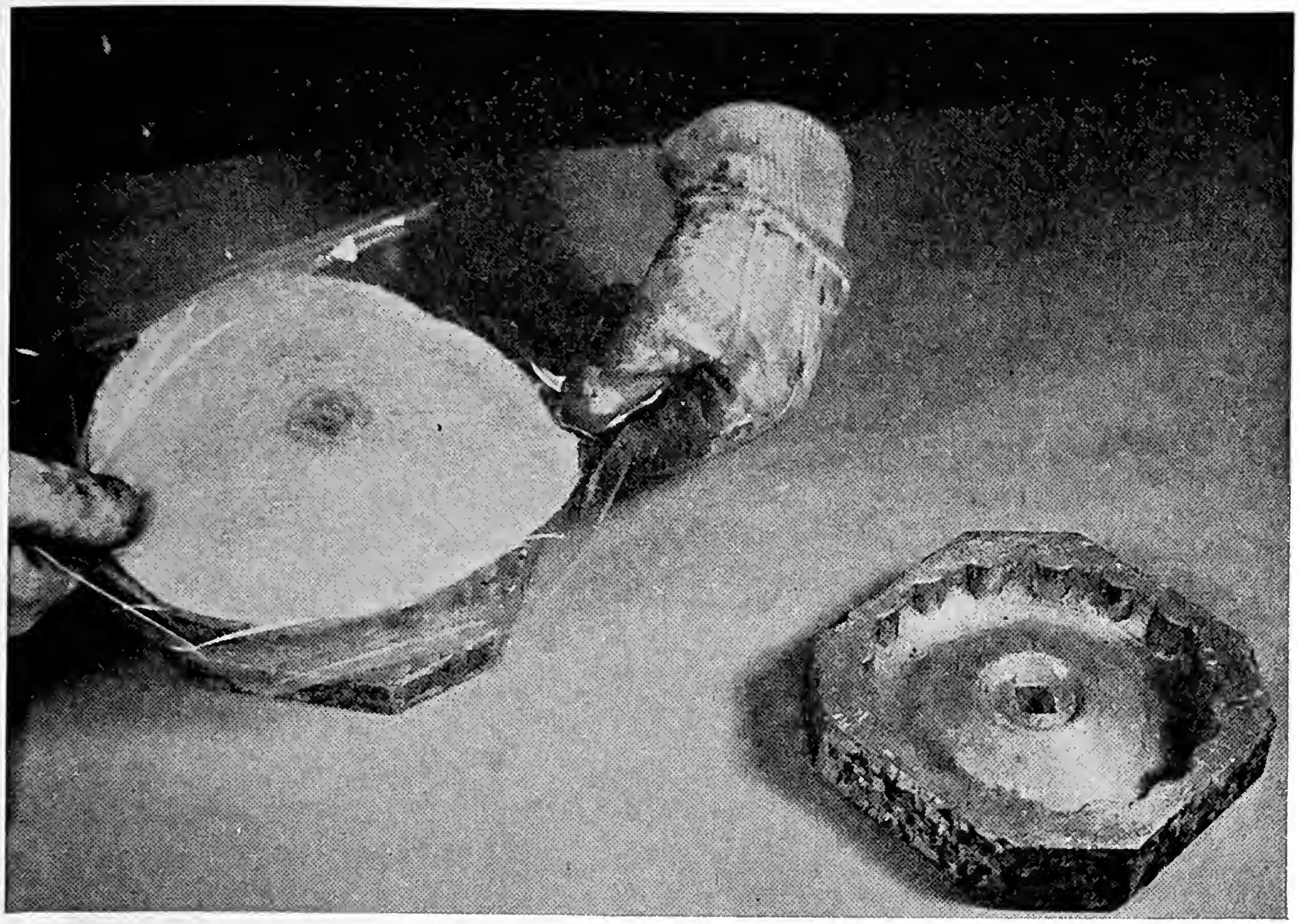


FIGURE 10. Placing assembly of resin coated mat with plastic film separator sheets on male die. Note pin in center to mold hole for valve stem.

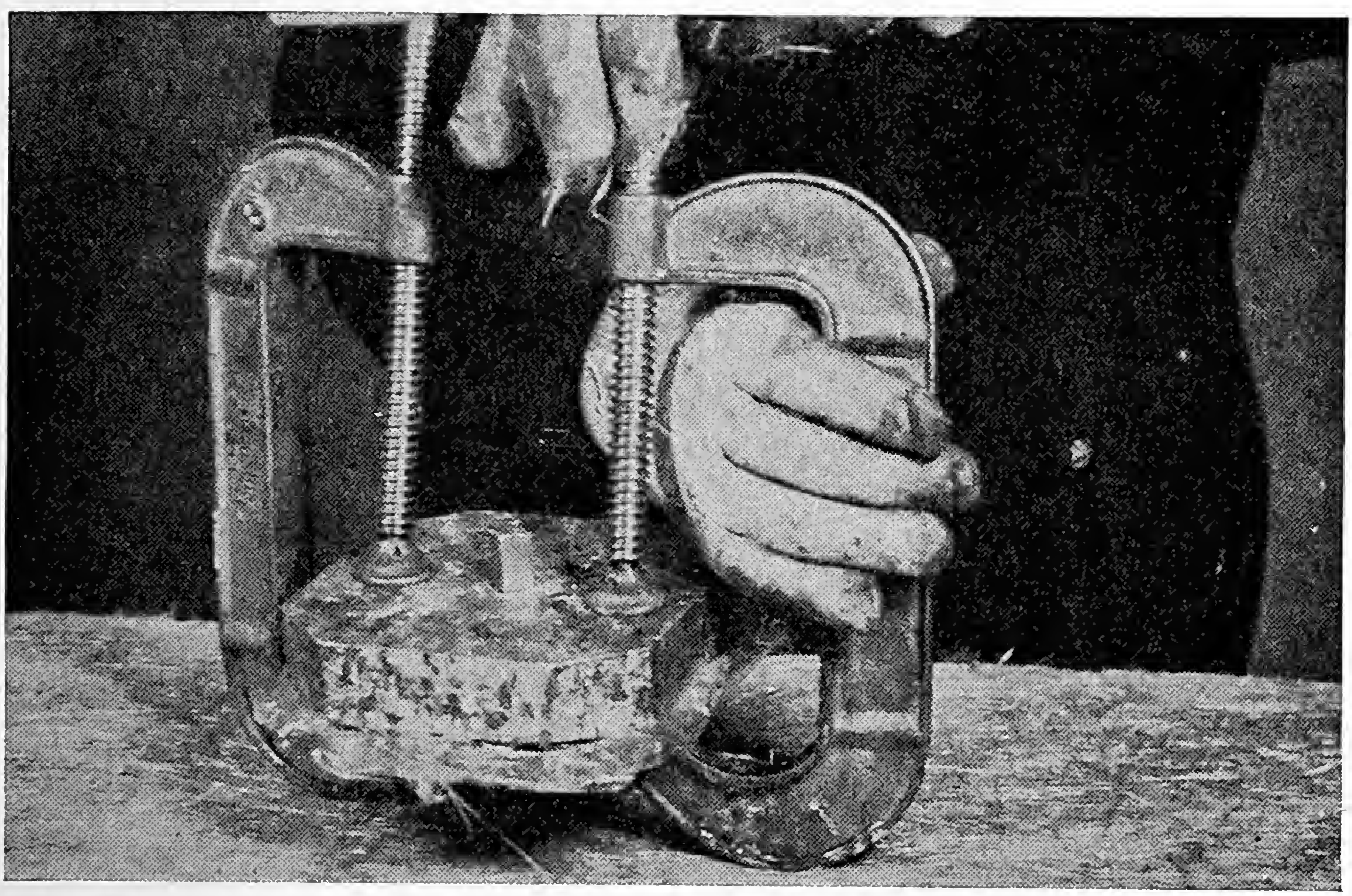


FIGURE 11. Fastening dies together with metal "C" clamps.

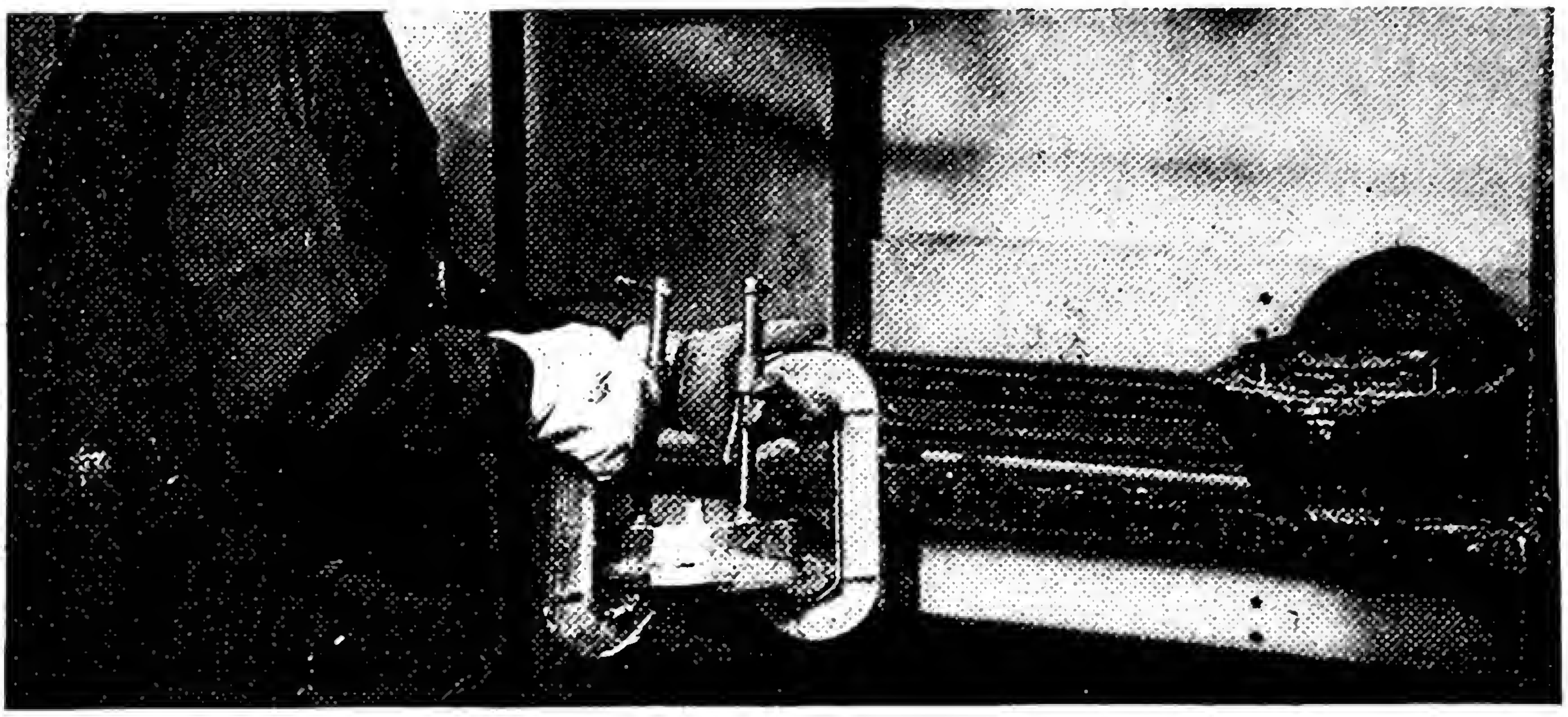


FIGURE 12. Placing assembly in oven to cure.

FIGURE 13. After curing. Knock-out pin being removed.

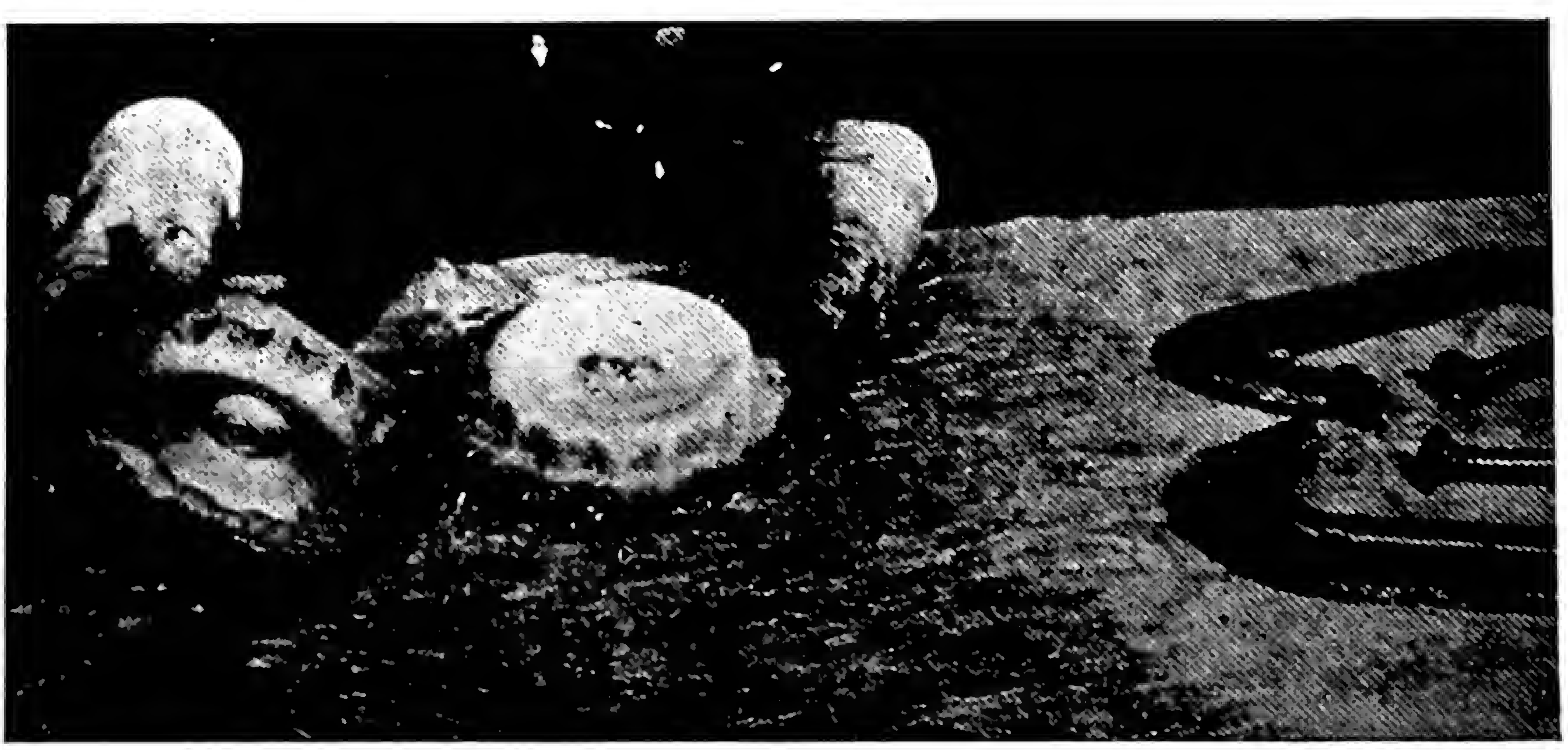


FIGURE 14. Female die removed from assembly. Note cured laminate yet in place on the male die or mold.

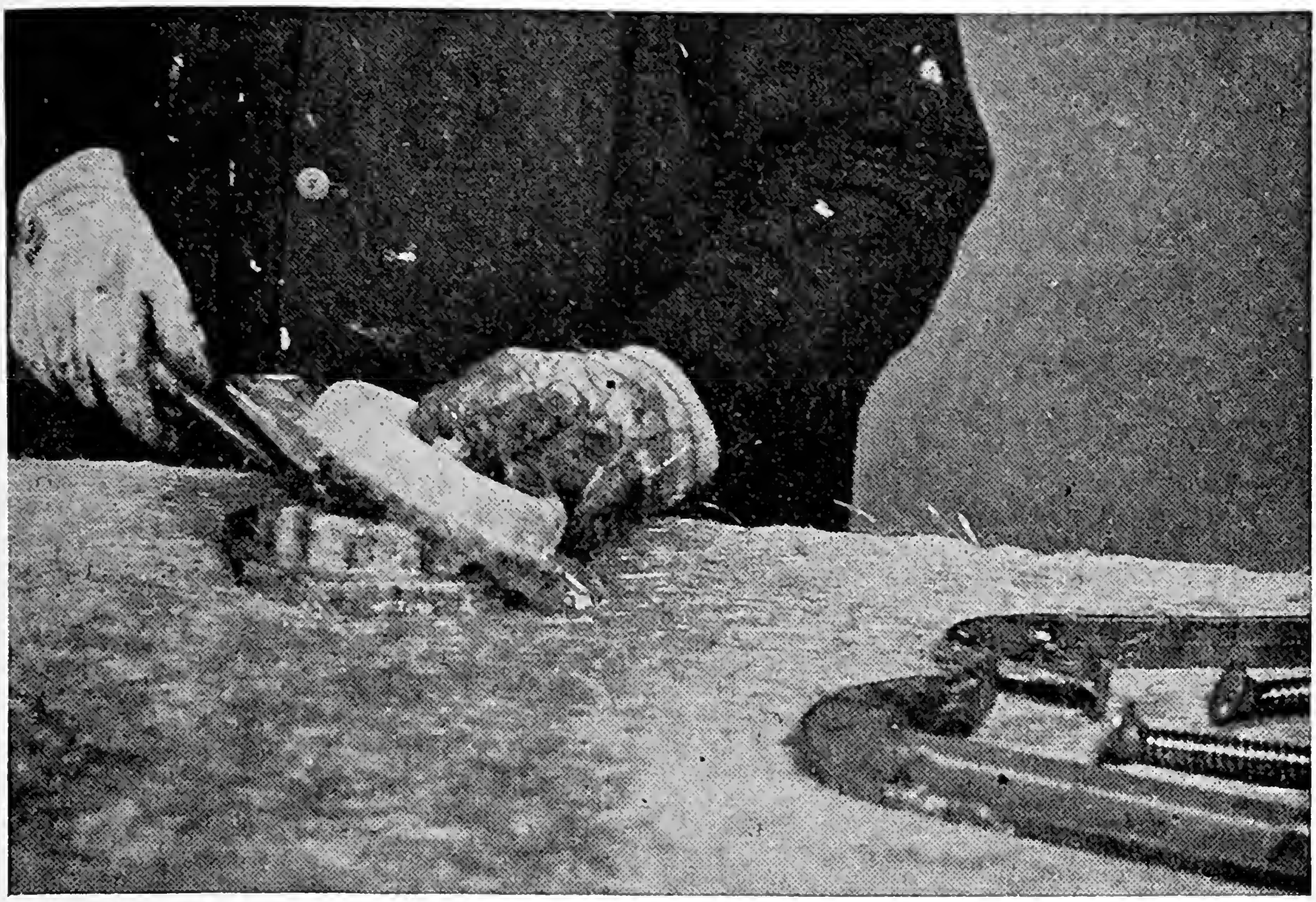


FIGURE 15. Prying molded valve handle from male die. Removal of plastic separator sheet and trimming remain to be done.

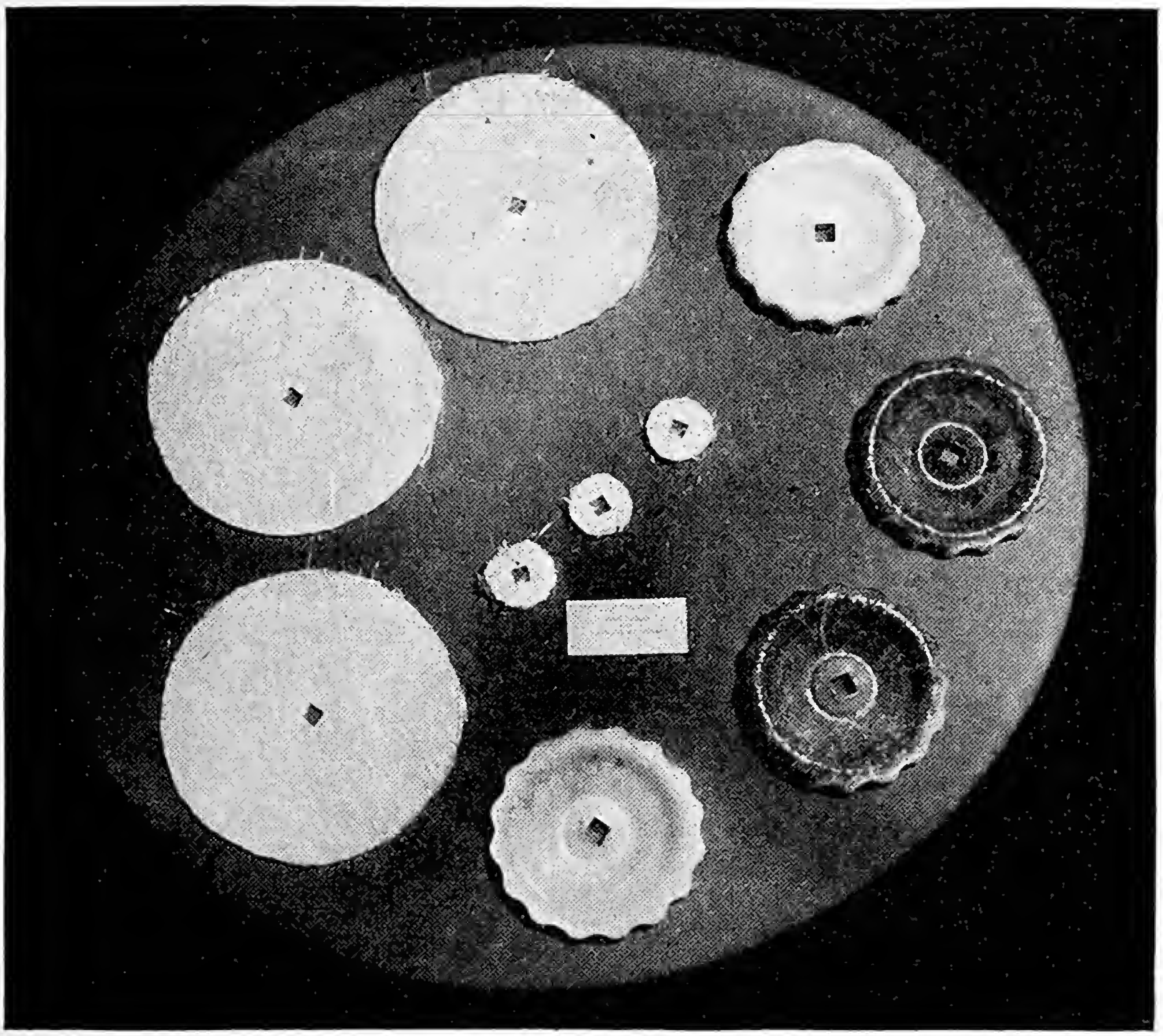


FIGURE 16. Four completed valve handles and mats used for the lamination.

Chapter 3
Resins, Catalysts and Curing

Selection of Materials

When one contemplates the fabrication of a low-pressure laminate there are three basic elements required, *viz.*, the mold, the resin and the reinforcement. In the preceding chapter the question of molds has been discussed. We now take up the subject of what resin to use. Figures 4 to 16 illustrate the lamination of a valve handle.

Following are listed some resins which have been used successfully in the low pressure laminating field:

Resin	*Approx. Price Per Lb.*	*Manufacturer*
Allymer Resins CR-39, CR-149 #170	$0.65-$1.15	Pittsburgh Plate Glass Co., Columbia Chemical Div., Grant Bldg., Pittsburgh 19, Pa.
Bakelite Resins BRS-16631, BRS-17582; BV-16238, BV-16887, BV-17085; XRS-69, XRS-81	$0.16-$0.45	Bakelite Corp., 30 E. 42nd St., New York 17, N. Y.
BCM Resin	$1.25	E. I. Du Pont de Nemours & Co., Arlington, N. J.
Catabond and Catavar Resins	—	Catalin Corp., 1 Park Ave., New York 16, N. Y.
Diallyl phthalate	—	Shell Development Co., 4560 Horton St., Emeryville 8, California
Durez Resins 12108, 12120, 12668	$0.17-$0.25	Durez Plastics & Chemicals, Inc., North Tonawanda, N. Y.
Durite Resins	—	Durite Plastics, Inc., Philadelphia, Pa.
Interlake Resins 4585 and others	—	Interlake Chemical Corp., Union Commerce Bldg., Cleveland, Ohio
Laminac Resins 4000, 4116, 4122, 4125, 4201		American Cyanamid & Chemical Co., 30 Rockefeller Plaza, New York, N. Y.
Melmac 403	$0.44-$0.55	
Marblette Resins	—	The Marblette Corp., 37-21 30th St., Long Island City, N. Y.
Marco Resins MR-1A, 17A, 17B, 17C, 17D	$0.45-$0.55	Marco Chemicals, Inc., Sewaren, N. J.

Resin	Approx Price Per Lb.	Manufacturer
Paraplex Resin P-10	$0.55	Resinous Products & Chemical Co., 222 W. Washington St., Philadelphia 5, Pa.
Plaskon Resin 911 and others	$0.66	Plaskon Division, Libbey-Owens-Ford Glass Co., 2112 Sylvan Avenue, Toledo 6, Ohio
Plyophen Resin 110-L-96	$0.18-$0.25	Reichhold Chemicals, Inc., 601 Woodward Heights Blvd., Detroit 20, Michigan
Resinox Resin 45815	$0.30	Monsanto Chemical Co., Springfield 2, Massachusetts
Thalid Resins X-535, X-540	$0.45	
Selectron Resins 5003, 5015, 5016 and others	$0.50-$0.60	Pittsburgh Plate Glass Co., Paint Div., Pittsburgh 19, Pa.
Synvar Resins V-2N	$0.55-$0.70	Synvar Corporation, Wilmington 99, Delaware
Vibrin Resin	—	Naugatuck Chemical Co., Division of U. S. Rubber Co., 1230 Sixth Ave., New York 20, N. Y.

Just what resin is to be used or what resins are to be tried for a given application is partly determined by an analysis of the product to be made. Important consideration will be given to the costs permitted, the functional characteristics needed in the laminate, the chemical and electrical conditions under which the laminate is to operate, and other factors. The physical strength required in the laminate is an important function of the reinforcing agent, because resins alone have low strength in contrast to well reinforced resins. For example, note the following figures:

	Resin Alone	Glass-reinforced Plastic
Tension	9,000 psi	45,000 psi
Modulus of elasticity	400,000 psi	2,400,000 psi
Compression	25,000 psi	33,000 psi
Flexure	10,000 psi	55,000 psi
Impact (per in. of notch) Izod	1.0 ft. lbs.	24. ft. lbs.
Moisture absorption	0.4%	0.4%
Specific gravity	1.3	1.8

Some resins are of a consistency equal to sirup and may be poured easily onto a mold already containing the reinforcing material, such as cotton, sisal or glass fibers. Other resins are of a heavy consistency, too thick to pour readily, and are more easily applied to the reinforcing material by means of a knife coater or "doctor

blade." An inexpensive machine may be built to coat cloth, or mats of material which have sufficient tensile strength to be pulled through a dip tank for less viscous resins or through a roller coater for more viscous resins. Squeeze rolls control the quantity of resin picked up.

There is a recent addition to the field of resins which should be mentioned at this point, although this resin is not likely to be used in large tonnages for some time, in contrast to the lower-priced resins now available in quantities of millions of pounds per year. This new resin belongs to the silicone family and is manufactured by Dow-Corning Corp., Midland, Michigan. The especial merit of this new resin is its stability at higher temperatures such as 400 to 450° F. Ordinary organic resin laminates begin to deteriorate at about 300° F, while inorganic filled laminates with organic resins begin to deteriorate at about 350° F.

If the resin softens the binder material used on the mat, then some form of drip impregnator is desirable.

Mats of reinforcing material which have a resin-soluble thermoplastic binder may not be handled as cloths are handled for the resin dip-coating operation. This is because the binder is usually softened by the solubility and miscibility with contact-pressure resins. Another method of handling is necessary to apply 50 to 60 per cent by weight of resin to the mat surface for even distribution.

The mat may be unrolled and fed onto a belt type conveyor; the resin ready for laminating may be placed in a tank three or four feet above a positive displacement gear type pump which should be driven by a variable-speed motor. The resin flows by gravity to the pump and is delivered in uniform quantity to a series of pipe manifolds over the mat. Each of these manifolds has evenly spaced projecting tips with holes which deliver uniform ribbons of resin to the mat. These resin ribbons disperse into the mat, thus providing even distribution.

To be sure that all these openings are delivering an even quantity of resins, keep increasing the speed of the pump until resin is flowing through all the openings; then weigh the amount of resin on the mat and regulate the speed of the conveyor to provide the desired resin content.

After impregnation, the mat should be rolled up with a layer of cheese cloth or similar material between each two mat layers. This operation packs the fibers down and gives the mat integrity, allowing it to be readily handled and laminated.

Manifold sections may be made of 1″ diameter pipe with tips spaced at $\frac{1}{4}$″ and holes $\frac{1}{16}$″ in diameter. Select a pump with sufficient capacity for the width of sheet used and the desired conveyor speed. Several manifolds one foot long should be used to facilitate uniform coating and to provide flexibility of widths which may be impregnated (see Figure 17).

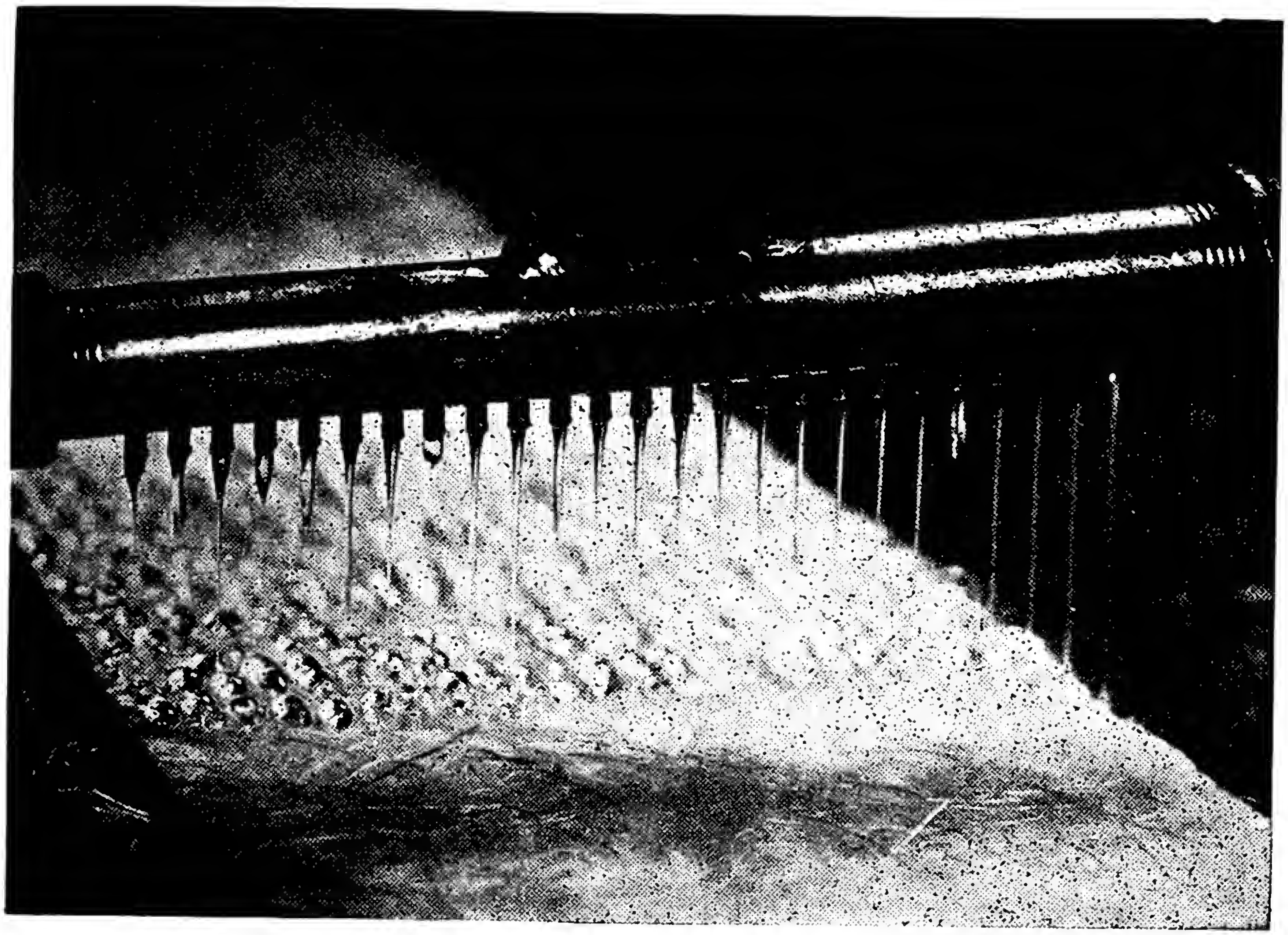


FIGURE 17. Drip impregnator used to apply uncured liquid plastic to glass mat.

The pump or pumps should be of the positive displacement type similar to those manufactured by the Kinney Manufacturing Company, 3564 Washington Street, Boston 50, Massachusetts.

It should be pointed out that various means may be used to facilitate coating of mat with a polyester resin. In flat sheet machines for continuous laminating, a wide mesh cloth scrim may be used to hold the mat. In dies where lay-up is made by hand or by semi-automatic equipment, the operator can use a wire screen

form to hold the mat in place while the resin is brushed on, flowed on, or otherwise applied. The screen wire holds the softened fibers in place while the required quantity of resin is applied.

In general, the use of a *catalyst* in a resin to hasten the curing rate so that the curing time cycle is shortened is little different from the more familiar use of "driers" in paints and enamels to hasten their polymerization rate. This means simply to dry or cure faster than if catalysts were not used. Some resins would require an unduly long time to cure or "set" hard enough to maintain their shape. Afterward the laminated parts could be baked in an oven to a complete cure.

Commonly used catalysts are certain organic peroxides. A partial list of materials and suppliers follows:

Benzoyl Peroxide:
Fisher Chemical Co., 60 East 42nd St., New York 17, N. Y.
Lucidol Corp., 1740 Military Road, Buffalo, N. Y.
Peters Chemical Co., 2575 Ewen Avenue, Kingsbridge, N. Y.
Seydel Chemical Co., 225 Mercer Ave., Jersey City, N. J.

Organic Peroxide FL:
Becco Sales Corp., Station B, Buffalo, N. Y.

Tertiary Butyl Hydroperoxide (especially for casting resins):
Union Bay State Co., Harvard and Main Sts., Cambridge, Mass.

It should be mentioned that another type of catalyst has been reported to be used for curing low-pressure resins. This has been called a "sunshine catalyst" or a photochemical accelerator. Benzoin is one among several such catalysts described in U. S. Patents Nos. 2,367,660 and 2,367,661. When used with conventional catalysts the thermosetting resins cure at ordinary temperatures in the presence of sunlight, natural or artificial types. Some resins themselves may be cured by photopolymerization. Such a "sunshine catalyst" has use for prototype work, but for production purposes the standard catalysts are serving very well at present.

The manufacturer of a resin usually supplies technical data regarding recommended curing temperatures and times for various thicknesses of laminates as well as the percentage of a certain catalyst to be used. Often the catalyst is received as a powder or in granules of 100 per cent organic active material. This is not so

readily and easily mixed into the resin by stirring as a paste form of the catalyst. Sometimes a paste form of catalyst containing 50 per cent by weight of the active ingredient is received. In most cases such a paste can be mixed into the resin within a few minutes with a good stirrer.

It has been reported that it is desirable to mix the catalyst into the resin and let the solution stand for a few hours before using it to coat cloth or to be subjected to the curing cycle. Other variables in the use of a catalyst should be carefully noted so that the best conditions are obtained. The resin supplier furnishes much data, but the individual shop has its own set of variable conditions to be taken into consideration, such as mixing equipment, storage conditions for the resin, coating facilities for cloth reinforcement, and the like.

Usually resins as received have a long storage life at room temperature, but after addition of the catalyst, the mixture or solution may have a useful life of a few hours to a few days. The "shelf-life" of a catalyzed resin is prolonged by storage at lower temperatures such as in a refrigerator at 40° F. Ultraviolet rays usually shorten the keeping life of resins.

Not only may the catalyzed resin be stored for longer times in a refrigerator, but the coated cloth or mat may also be stored in this fashion and used in succeeding days for various laminating tasks. Thus a sizeable quantity of resin could be mixed and coated onto cloth, which is stored in the cold room.

When one investigates the phases of mass production technique —the broad phases are relatively easy to set up—the lay-up and assembly operations, the molds and curing cycle, ovens, and the finishing equipment.

The resins are important and they may require modification to adapt them to the system of laminating being used. The item being manufactured and its construction dictate the details of the whole production set-up. For example one laminator used two metal molds, differentially heated so that a smooth, glossy finish resulted on one side of the laminate. The resin had to be suitable for penetration of the reinforcing materials which had very different characteristics. The manufacturer of the resin spent considerable development effort on the following separate variables of his product:

(1) *Wetting* of the fillers, which involved surface tension problems;
(2) *Penetration* of the cardboard portion of the filler, which involved diffusion problems;
(3) Balanced and controlled *flow* in the mold both before and during the curing cycle. The problems were solved by incorporating suitable additives with the resin, such materials being compatible, not inhibiting the cure, or otherwise interfering with the desirable characteristics needed for successful laminating.

The use of good *colors* in resins is very limited. The manufacturer of Selectron resins supplies colors in the form of both dyes and pigments for use with their product.

The manufacturer of Laminac resins supplies preliminary information on the use of six organic toners in various colors. It is suggested that approximately 70 parts of toner be ground with 30 parts of diallyl phthalate or some other material compatible with the resin. Usual pigment dispersion methods may be used, such as the ball mill or colloid mill. Nine colored inorganic pigments are described, and when dispersed in the same way as the organic toners, they have better fastness to light. Dyes are also furnished for coloring cured resins. Because of the difficulty in using a color material with the resin which will withstand the curing conditions, and yet be uniform in shade and "fast" to sunlight, considerable effort has been devoted to adding color afterward.

Plastics may be colored by means of after-treatment with solutions of dyes. Some suppliers of these solutions are:

"Rez-N-Dye" (cold dip dye) Schwartz Chemical Co., 326 W. 70th St., New York 23, N. Y.

"Kriegr-O-Dip" plastic dyes, Krieger Color and Chemical Co., 6531 Santa Monica Blvd., Hollywood 38, California.

"Aqua Plastic Dyes," Great American Color Co., 2512 W. 9th Street, Los Angeles 6, California.

"Rez-N-Dye" is supplied in a variety of colors. The plastic article is immersed in the dye until it acquires the desired depth of color. It is then removed, rinsed in water, and dried. The intensity of color is controlled by the time the article remains in contact with the dye solution.

"Kriegr-O-Dip" is supplied in a number of colors. It is applied by dipping, spraying or painting.

"Aqua Plastic Dyes" are applied from a hot water solution at about 200° F. Various colors are available. They are suitable for dyeing melamine laminates. The desired shade of color is controlled by varying the immersion time from 30 seconds to approximately one minute.

To obtain a *glass-smooth colored surface on a laminate,* the following procedure may be followed: Use resin pigmented with the desired color. It is preferable to use 70 to 75 per cent of regular laminating resin and 30 to 25 per cent of flexible laminating resin. Brush onto prepared mold surface carefully or spray on till a film of 0.010″ to 0.020″ is formed. Cure for two to ten minutes to a "gelled condition," *i.e.,* yet tacky but not fully cured. Three to five thin layers may be cured consecutively rather than one heavy layer. Lay-up the resin impregnated reinforcing material. Cure the complete assembly in the usual manner.

With regard to color in laminates it may be mentioned that most carbon blacks and most organic dyes inhibit the cure. A limited number of dyes can be successfully used with low-pressure resins. With high pressure, phenolic or urea resins, usually an acid or alkaline catalyst is used. Consequently an acid or alkaline stable type of dye must be used. With low-pressure and contact resins, peroxide catalysts are normally used. The type of dye used must therefore be unaffected by the peroxide catalyst.

Luminescent Pigments include fluorescent, phosphorescent and radium active types. These may be used to accomplish a variety of novel effects in plastics. For example a red daylight color may be achieved and the flourescence will still be white. Under the trade name of "VIOLITE" these pigments are made and sold by:

Rhode Island Laboratories, 100 Pulaski Street, West Warwick, Rhode Island.

Mixing of resins with pigments is facilitated by use of Simpson intensive mixers which operate with a so-called "mulling action." These mixers are manufactured and sold by:

National Engineering Co., 549 West Washington Blvd., Chicago 6, Ill.

Curing

We now come to a discussion of the *curing* of the resin. There are a number of topics to be considered from the standpoint of small-scale work in a laboratory as well as the larger-scale work in the shop. In the small-scale work for testing various resins as well as checking the optimum conditions for curing, a small laminating press is very helpful. Such a press may be obtained from:

Fred S. Carver, 345 Hudson St., New York 14, N. Y.

When curing is to be done under low pressures, such as may be obtained by evacuation of air from the envelope surrounding the mold, a small vacuum pump hooked up to a storage tank such as a 30-gallon hot-water tank makes a good combination. Two suppliers of such vacuum pumps along with a fractional horsepower electric motor to drive it are:

Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.
Central Scientific Co., 456 East Ohio St., Chicago, Illinois.

Small ovens for curing low-pressure laminates may be obtained from:

American Instrument Co., 8010 Georgia Ave., Silver Spring, Md.
G. S. Blodgett Co., Inc., 50 Lakeside Ave., Burlington, Vt.

When a mold has been properly prepared and is ready to receive the laminate, one may use contact pressure of $\frac{1}{4}$ to $\frac{1}{2}$ psi, such as may be obtained by placing a weight upon the material. For pressures of 5 to 10 psi it is desirable to use a bag surrounding the entire assembly. The bag would then be evacuated by means of a vacuum pump hooked up to a suitable connection such as an inner tube valve stem inserted in the sheet. One convenient material to use for a bag is polyvinyl alcohol sheeting, 0.003″ thick, and supplied by

Resistoflex Corp., Belleville 9, N. J.

Reference

"Vinyl Bags for Low-pressure Molding," *Modern Plastics*, page 133 (Feb. 1946).

A rubber bag or envelope may be used to surround the entire mold, or in some cases where the mold and technique used permit,

a rubber blanket or sheet is permissible. Suppliers of such material are:

Goodyear Tire & Rubber Co., Akron, Ohio.
Tyer Rubber Co., 100 Railroad Ave., Andover, Massachusetts.

Another rubber material which has been used to cure reinforced plastics is the "Uskon" heating pad as supplied by:

The United States Rubber Co., 1 Market Street, Passaic, N. J.

This pad acts as a resistor and heats up when the electric current is applied. Parts may be cut out and heat applied to areas as selected. This is especially useful and time saving when thick plaster of paris molds are used with relatively thin laminates. No oven is required for such a heating method.

The use of molds, resins and catalysts in the curing cycle has been described thus far as largely consisting of slow, hand work. This is quite true for much laminating now done by the low-pressure technique. Nearly every job is a custom-built, individually engineered, tedious task. The hat-press type system involved some mechanization in the process. This makes use of a cast aluminum or bronze male or female mold sections with a rubber bag, plus hydraulic pressure. There are also the autoclave method and the rubber blanket process.

Reference

"Low-Pressure Molding of Laminates," by F. P. Wilson and N. D. Harrison, *Modern Plastics*, page 57 (Aug., 1943).

Heating of molds during the curing cycle may be accomplished with electricity, with steam, with infrared lights, or by placing the whole assembly in an oven. In recent months high-frequency dielectric heating has become more widely used. Suppliers of such equipment are:

Federal Telephone and Radio Corporation, Newark 1, N. J.
General Electric Co., Apparatus Dept., Schenectady 5, N. Y.
The Girdler Corporation, Thermex Division, Louisville 1, Kentucky.
Radio Receptor Co., Inc., 251 W. 19th St., New York 11, N. Y.
Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa.

In conventional methods of heating, the rate of heat transfer is largely a function of the conductivity of the material. These

methods of conduction, convection and radiation are well known. In induction or dielectric heating, the rate of heating is limited only by the ability of the material to receive heat without being destroyed. Motor generators, spark-gap oscillators and electronic generators are used for this purpose and are designed for various ratings.

The degree to which non-conducting materials will heat is a measure of their insulating qualtities. An alternating electric field passing uniformly through a non-conducting material displaces or stresses the molecules of the material, first in one direction and then the other, as the polarity of the field is reversed. Heat is generated as a result of friction due to this molecular motion. The heat generation is proportional to the field reversals per second; hence, the higher the frequency, the faster the heating. Voltage and frequency dominate dielectric heating. Faster and less costly manufacturing techniques often result from the use of dielectric heating. For example, thick phenolic laminates were cured more uniformly and more quickly, and danger of overcuring avoided by use of radio frequency (r.f.) heat. In conventional compression molding use of r.f. preheating accomplished savings in mold costs, curing time and maintenance, as well as increases in production, mold life and material savings.

Electronic preheating has proved its value in transfer molding because improved physical properties result from the increased plasticity of the preheated charge. Some of the lessons learned in this field may be applicable to the field of low pressure laminates on the production line.

In good molding practice all flow of the resin should cease before it cures or polymerizes to the point that further movement would cause structural weakness. It is desirable to shorten the cure cycle so long as good strength properties can be maintained and a safe working ratio exists for time in the mold before setting. By this is meant that if 5 seconds are required to close the mold, and setting up comes in 15 seconds, then we have a ratio of 3:1. This is too short and too critical to be safe. A ratio of 8:1 is much safer and does not jeopardize the molding operation cycle. It is likely that ratios of 10:1 or even 15:1 may be required for very large parts, especially if the mold closes on some areas first, then upon other areas by means of selective pressure application techniques. A

lower percentage of catalyst should increase the ratio, cooling the resin before placing it in the mold should also delay the setting-up so that the safety factor is more favorable.

When the curing of pre-formed material is carried out on dies or molds which are continuously heated, it is desirable to check the surface temperature of the mold to be sure the desired curing temperature is maintained. A surface temperature measurement may be made with a surface pyrometer, which may be obtained from the following concerns:

Cambridge Instrument Co., 3059 Grand Central Terminal, New York 17, N. Y.

The Pyrometer Instrument Co., 103 Lafayette St., New York 13, N. Y.

Illinois Testing Laboratories, Inc., 420 N. LaSalle St., Chicago 10, Ill.

For a short time cycle of curing there is a wide variation in temperature for various classes of resins:

for phenol-formaldehyde resins, up to 350° F
for melamine-formaldehyde resins, up to 300° F
for thermosetting ester resins, up to 300° F
for urea resins, up to 225° F and
for thiourea resins, up to 150° F.

Since the field of high-pressure laminating is rather old and established, many materials have been designed to meet the curing conditions of that field. Resins of a condensing type which form reaction by-products, such as water and ammonia, during the chemical reaction of polymerization, are subjected to such high pressure that gases are held in solution and the laminate is free of bubbles or voids. When such a resin is cured at much lower pressures, the volatile materials cause "blush" spots from water, as well as bubbles and pin holes in the laminate. Naturally these voids result in a lowering of tensile strength and other properties, just as termite holes weaken a two-by-four. This fact of bubbles in a laminate fabricated at low pressures has been called to the attention of the resin manufacturers. Some of the lowest-price resins such as phenolics cannot yet be used at low pressures for this reason; however, Bakelite BV-17085 is a contact-pressure phenolic producing the strongest glass laminate ever obtained.

In the curing step too much pressure or mold defects may result in damaged fibers, undercured laminate, variable density of the

laminate or poor resin flow. Common surface defects are blisters, slippage of the surface layer, resin pockets, "starved" spots of insufficient resins, and wrinkles. The resin pockets may form if sharp angles are present in the female mold. A sharp-cornered external angle is undesirable because of its mechanical weakness. A smooth-curve corner design gives good strength in a laminate which is free from resin pockets. When such reinforcing members as ribs are to be molded into a structure, they should be so formed as to give gradual or tapered contours between thin and thick sections.

Warpage is to be avoided in laminates of flat sheets or of contoured parts. One principle to be observed is a "balanced" lay-up or sometimes called symmetrical construction about the central or neutral axis. If five plies are used, consisting of three paper and two glass mat, there are two possible balanced constructions as: P-G-P-G-P and G-P-P-P-G. In each case one ply of paper is located at the neutral or central axis.

When melamine resins are molded at 250 psi, minimum warpage results when the laminate is cooled under pressure. Better gloss and abrasion resistance however are obtained at higher pressures such as 800 to 1000 psi.

When an unbalanced construction is used, warpage is often avoided by holding the hot cured laminate in a wooden form until it is cooled.

Before we turn to a detailed description of a self-sealing cover for a mold equipped with a rubber blanket or bag, the following references on low-pressure laminating are cited for additional reading material:

References

"Low Pressure Laminates for Aircraft," by Powel Crosley III, *Modern Plastics*, page 54 (Jan., 1943).

"Laminating by Low-Pressure Method," by J. D. Nelson, *General Electric Review*, page 483 (Sept., 1943).

"Low-Pressure Molding for Aircraft Construction," by Arthur W. Loerke, *Plastics*, page 68 (June, 1944).

"An Evaluation of Low Pressure Laminates," by L. M. Perdue, *Plastics*, page 38 (Sept., 1945).

"Low Density Laminates," by C. A. Scogland, *Plastics*, page 74 (July, 1945).

"Molding by Low Pressure," by W. Burdette Wilkins, *Plastics*, page 102 (July, 1945).

"Silicone Resin-Bonded Laminates," by L. V. Larsen, J. J. Whelton and J. J. Pyle, *Modern Plastics*, page 160 (March, 1945).

"Impression Molding," by R. W. Crawford and I. B. Nathanson, *Modern Plastics*, page 161 (April, 1946).

"Low-Pressure Laminate Plastics," by George H. Tweney, *Aero Digest*, page 75 (Feb. 1, 1945), and page 86 (March 1, 1945).

Present practices of laying-up resin-coated cloth or mat are rather slow and tedious. Much work is being done to develop more expeditious techniques to accomplish this step by the use of fewer manhours at a lower cost, so that the price of the finished laminate is in the realm to be considered by the potential customer. After all, any new product must do a better job at the same cost, do the same job at a lower cost, do a job no other product can do, or effect corollary savings which will justify the customer's purchase of that product.

The present development of the manufacture of low-pressure laminates is comparable with the state of the art of building automobiles in about the year of 1909. Improved materials and improved processes are now required to mechanize the various steps with lower-cost raw materials so that larger market volumes may be achieved. In fact, one can peer into the crystal ball of the future and see this very thing coming—and sooner than many believe possible.

Beginning with the present technique of curing a laminate under a rubber blanket, in which oftentimes many "C" clamps are used all around the mold as shown in Figures 18 and 19, it is desirable to eliminate these clamps with the time-consuming operation of sealing the mold.

More rapid production can be facilitated by use of a newly developed technique (patents pending) which is applicable to any size or shape for any kind of mold material.*

A flat sheet or a metal or plaster mold, either male or female type, may be used as a curing plate so long as there is a reasonably flat sealing edge about 2″ wide all around the perimeter of the mold. It is easy in practice to form this in plaster of paris when the original mold is made. It is also practical to form a sheet-metal mold with such an edge, or even to rework a metal mold by fastening to it

* Description of this vacuum-sealing technique is reprinted here by permission. Published in the magazine *Industrial Plastics* (August, 1946).

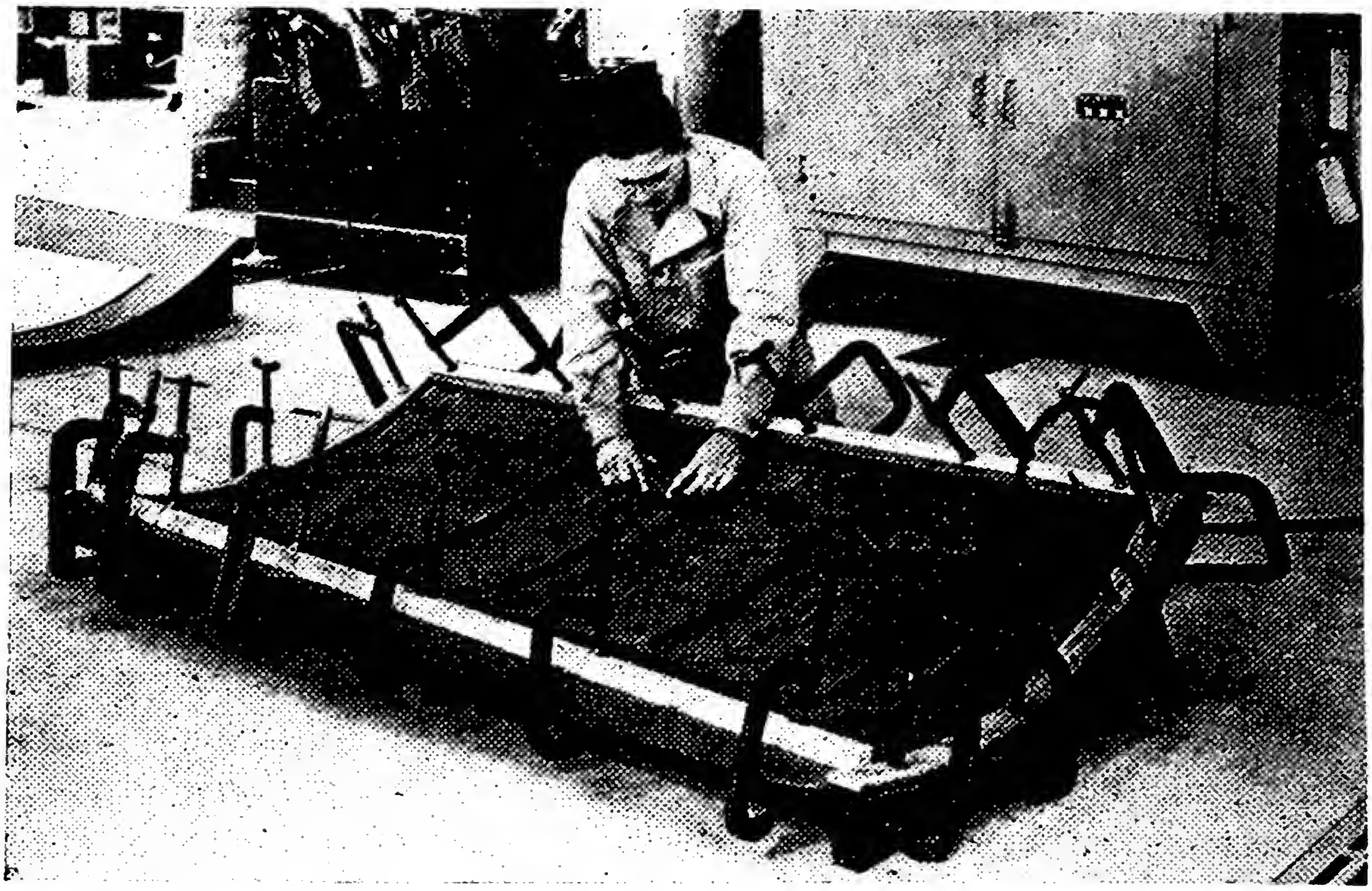


FIGURE 18. Illustrating a flexible blanket over a mold fastened with metal clamps.

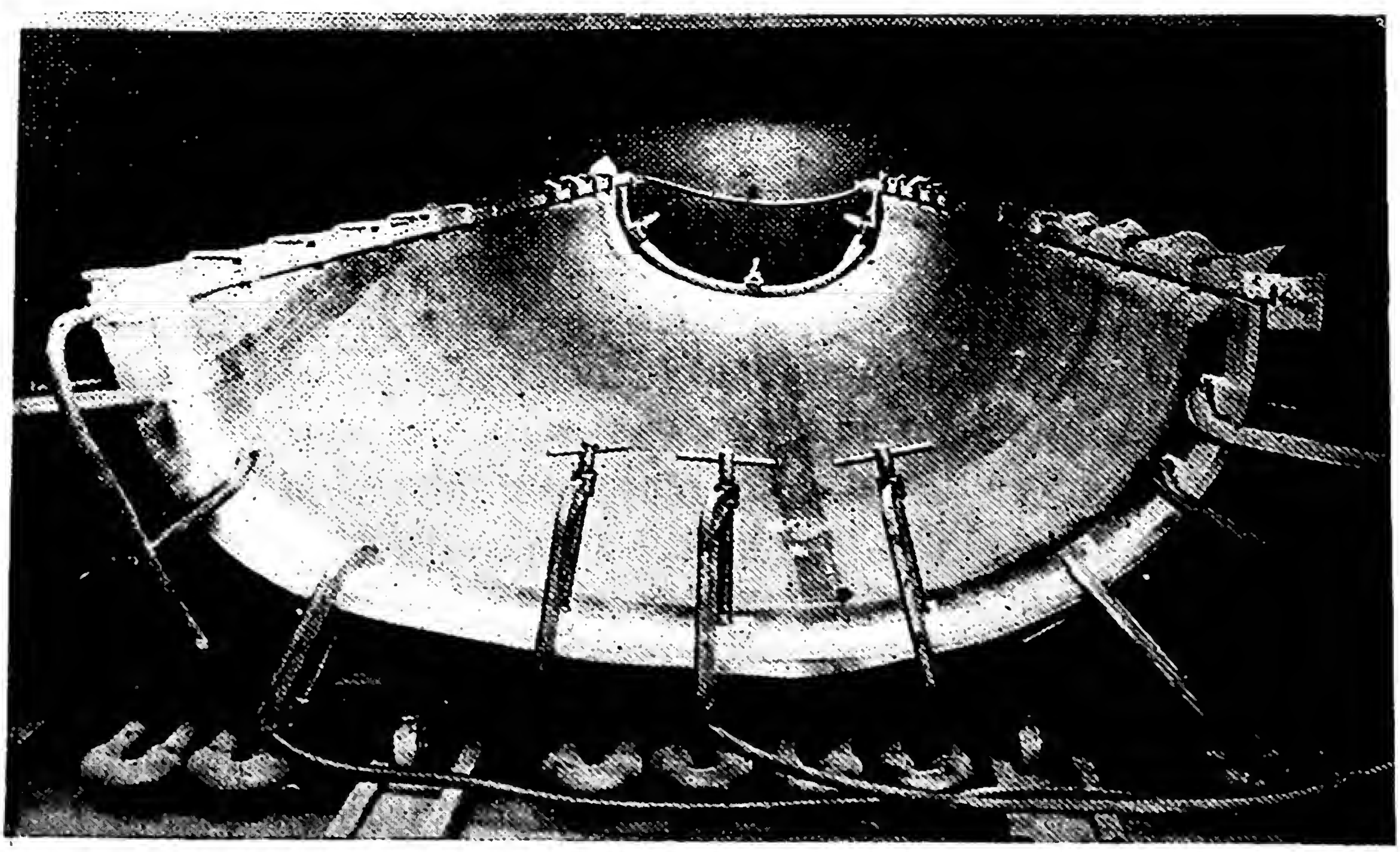


FIGURE 19. Another mold covered with a flexible blanket, held in place by means of metal clamps.

an extension skirt of metal to form a reasonably flat sealing edge about 2″ in width.

Figures 20 to 22 show an aluminum molding plate using such a system for closure.

A removable polished aluminum mold for an ash tray is located in the center of an aluminum plate about 1″ thick. On the bottom of this plate the electrical heating unit is located. Holes are drilled in each corner of the mold for attaching the vacuum line.

Figure 20 shows the lid closed with the rubber blanket drawn down firmly against the mold. This condition is maintained for the two-minute curing cycle for thin laminates. Heavier laminates may be partially cured to "shape" under vacuum, then "after-baked" to a final cure.

This flat sealing edge of the mold itself is one surface for the closure to be made, such as is used with a vacuum bag. With such a technique, it is not necessary to use a complete rubber or polyvinyl alcohol bag but merely sufficient rubber or other sheeting to cover the total area of the mold on one side. Obviously, sufficient freedom of movement of the rubber bag must be present for a vacuum to accomplish contact pressure over the entire surface of the mold; otherwise, certain areas may be "sealed off" and consequently cured improperly. In the case of molds of very irregular shape, it may be necessary to place uncured rubber along the contours and then cure it, so that when used there is sufficient stretch or elasticity in the sheeting to result in complete coverage of the mold area.

The cover sheet to be used as a sealing member on such a mold is characterized particularly by a rigid member such as 16-gauge metal, cut about 2″ wide and extending around the entire perimeter of the mold so that it will fit on the flat sealing edge already mentioned. This metal shape or collar may be welded at the corners or other joints and ground down to a reasonably smooth finish, that is, by removing burrs and very rough spots.

On the upper side of this metal collar the rubber bag or rubber sheet may be cemented or vulcanized or otherwise fastened tightly. On the lower side of this metal collar, which comes in contact with the sealing surface of the plaster or metal mold, it is necessary to attach gasket materials as described in the following paragraph.

One suitable method for sealing is to use strips of sponge rubber gasket material approximately $\frac{3}{4}$″ wide and $\frac{1}{2}$″ thick. One strip of

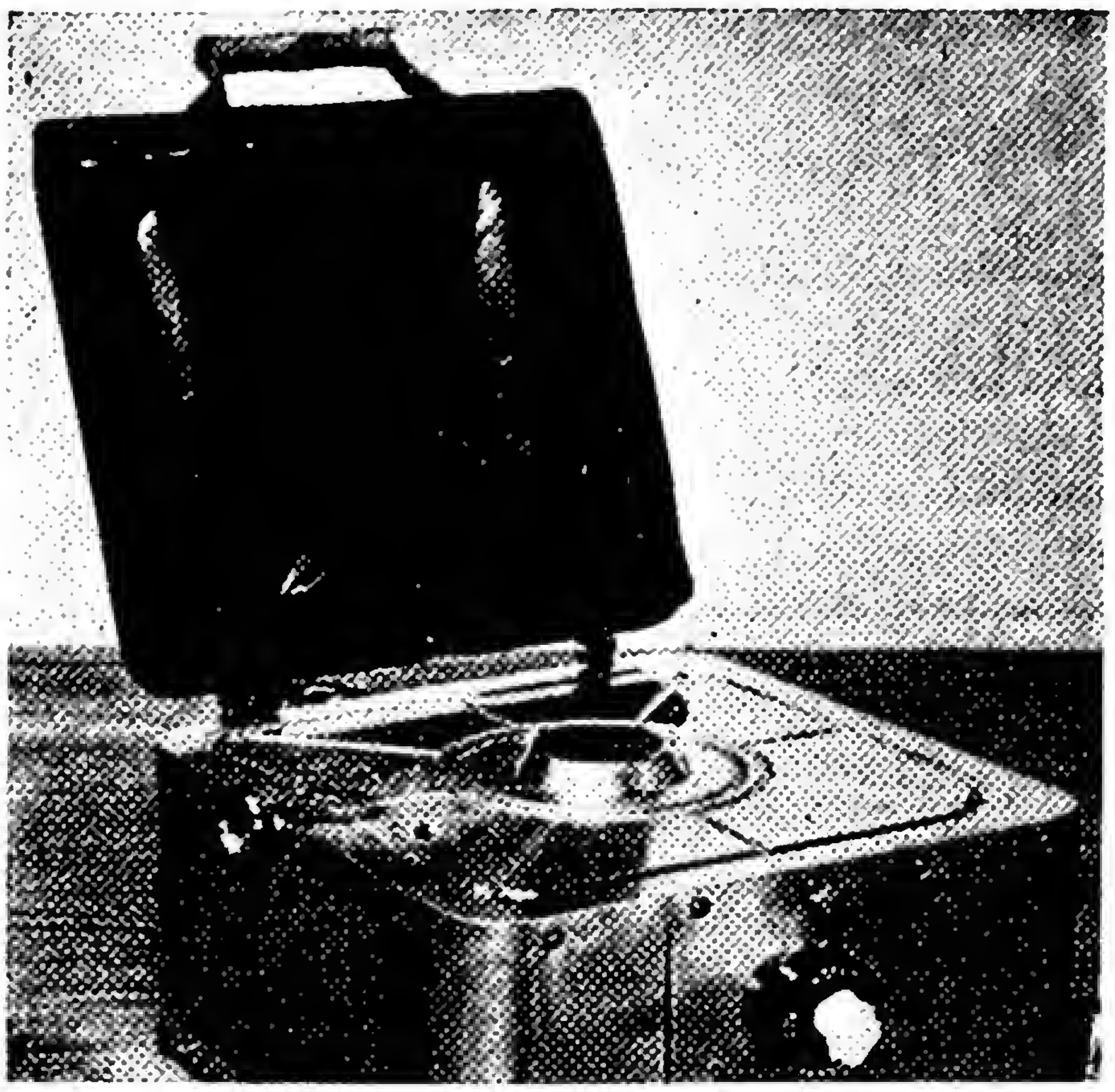


FIGURE 20. Self-sealing curing fixture to mold an ash tray. Note sponge rubber gaskets on the lid. Outer gasket is continuous for sealing. Inner gasket is discontinuous. Flexible rubber blanket is attached to the lid.

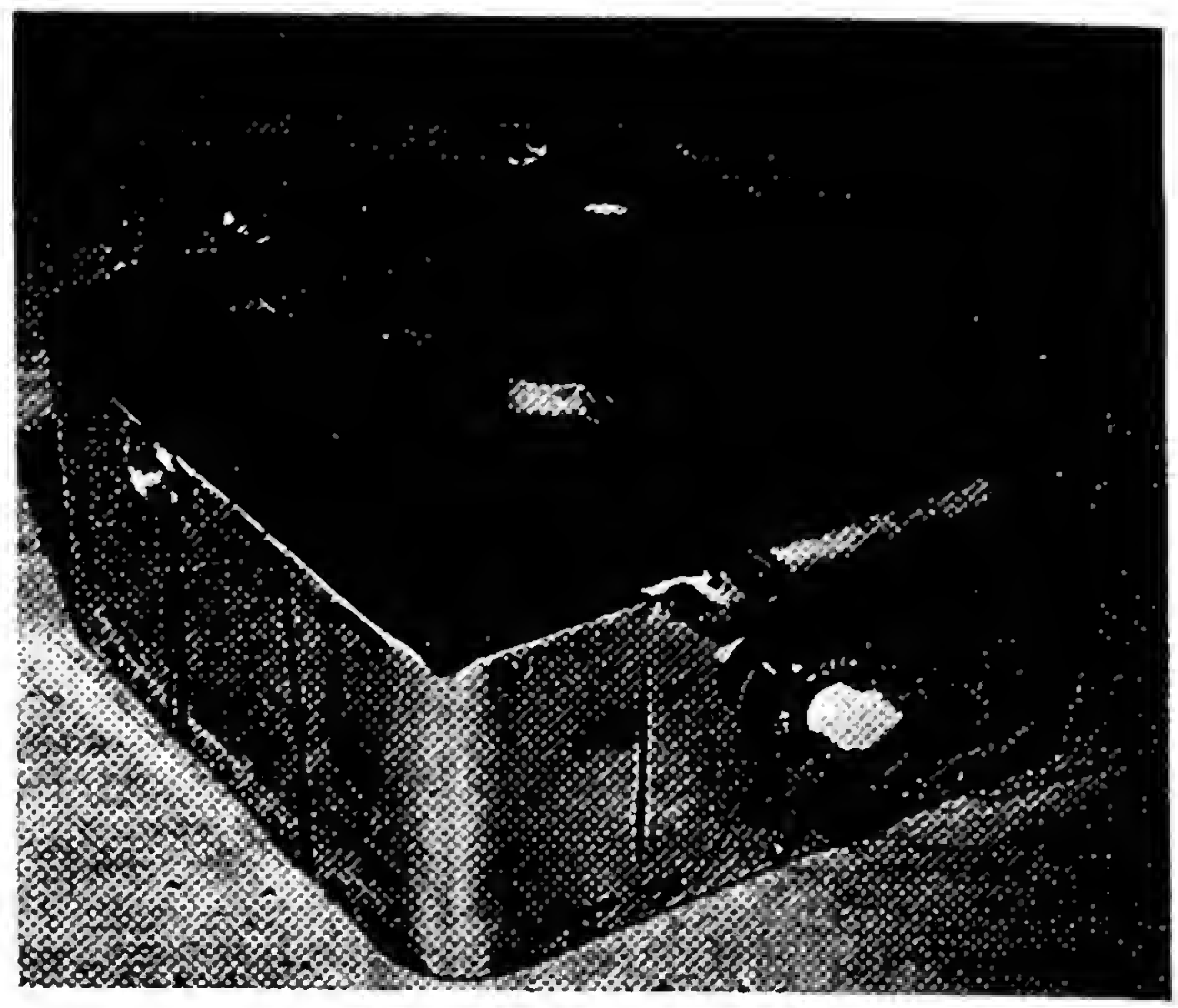


FIGURE 21. Fixture in closed position with vacuum applied. Note pressure exerted against aluminum mold during curing cycle. Fixture is electrically heated.

FIGURE 22. Release of vacuum permits lid to be raised immediately. Molded ash tray has been trimmed.

this gasket material is cemented to the outer edge or perimeter of the metal collar, all the way around. Care is taken at corners or other points where the gasket is jointed to make as airtight a seal as possible, because this gasket is the sealing member for the vacuum to be drawn inside the bag. A second sponge rubber gasket is cemented to the inside perimter of the metal collar on the face next to the mold, but in this case gaps of 1″ or 2″ are left; these are spaced perhaps 8″ to 12″ apart around the entire inner perimeter. These gaps in the gasket permit the flow of air from the channel between the two rows of sponge rubber gaskets so that the area inside the sealing gasket and underneath the metal collar is evacuated. In such a condition, pressure is exerted on a large part of the upper side of the metal collar and transmitted to the two rows of sponge rubber gaskets described, so that the outer gasket accomplishes a quick, effective vacuum seal, while the inner sponge-rubber gasket acts as a supporting bridge for the metal collar. Gasket material may be obtained from:

Sponge Rubber Products Co., 216 Derby Place, Shelton, Conn.

In such a system, the connections for evacuation may be made through the metal collar into the annular ring all around the mold, or they may be made through valve stems fastened into the rubber bag itself. Other more convenient attachments for the evacuation connection may occur to the reader.

In the operation of this system, quick closure of such a vacuum seal is aided by the use of a vacuum pump with a storage tank of adequate capacity used along with a "quick-opening" valve set in the line as close to the mold as is practical. In experimental work, using a flat sheet approximately 20″ × 20″ in size with a 30 gallon storage tank reading 27″ to 28″ vacuum, a quick-opening valve attached to such a system results in a gauge reading of about 25″ vacuum in about one-fifth of a second.

In the curing operation it is usually necessary to use a parting compound, as pointed out in Chapter 2. For production purposes such a mold release agent or parting compound should permit rapid removal of the cured laminate from the mold. One of the most satisfactory methods of insuring quick release at the present time is to use a liner between laminate and metal mold. For example, cellulose acetate flat sheet may be shaped to fit the mold.

In the case of male and female molds two plastic sheets may be used. In such a case the laminate and liners may be instantly removed from the molds and a new curing cycle begun.

Provision for such a shaped formation of thin thermoplastic sheet material pressed or drawn while heated to plasticity by means of a forming die, is covered by U. S. Patent 2,357,806 to G. W. Borkland of Borkland Laboratories, Marion, Indiana.

Reference

"Low-Pressure Laminating Adaptable to Large Parts," by T. N. Willcox, *Product Engineering*, page 386 (June, 1944).

When using the rapid production technique with a vacuum closure of the blanket or bag on the mold, as described on the preceding pages, it is sometimes desirable to provide a smooth surface on both sides of the laminate. This can be facilitated in a feasible manner by the mold design described as follows: use a female mold which extends outward to include an unheated or water-cooled portion at and adjacent to the flat sealing edge around the perimeter of the mold. Use a preform of thin metal, such as aluminum or stainless steel, shaped to the approximate contours as if it were a male mold. The metal is sufficiently flexible to be deformed to the variable thickness of the laminate being cured. This metal form is shaped to include a flat "skirt" in the same plane as the sealing edge, but some 6″ to 8″ removed from the perimeter of the mold. A rigid flat sheet of metal, some 2″ or 3″ wide, for the sealing edge surrounds the mold. To this flat sheet the sealing sponge rubber gaskets are fitted on the side adjacent to the mold. The next step is especially important: a sheet of rubber is used to join this flat sealing sheet to the flat skirt of the flexible metal form. Thus the complete assembly is made for the combination self-sealing blanket consisting of the rigid metal frame joined by an elastic sheet to the flexible metal inner member. This provides a metal blanket, with elasticity, which is not harmed by fatigue, as in a metal bellows connection, nor by continuous heating cycles, as is true of a full-size rubber blanket. The production life of the rubber sheet is prolonged by keeping it cooler, especially when using new low-cost, low-pressure type phenolics at higher temperatures for a very short curing cycle. With such a system

over a thousand laminates can be made before the rubber portion requires replacement.

Compression Molding

For many years high-pressure molding has been growing into a large industrial field in contrast to the new small industrial field of low-pressure lamination of plastics. Some lessons have been learned in this field which should be helpful to the growth and development of the newer field of molding at lower pressures. Let us therefore consider briefly the subject of *compression molding*—one of the oldest methods of converting plastic materials into useful plastic pieces. It has been used for years with high-pressure thermosetting resins, and considerable data are available from many sources on the compression molding of high-pressure resins. The principles involved are reviewed here briefly because many of the techniques of high-pressure molding can be used with low-pressure resins. In some cases the properties of the low-pressure resins may be preferred in the molded plastic piece. In any case, the capital outlay will be less because at the lower pressures, lighter-weight equipment is required.

The resins most commonly used in high-pressure molding are phenolics, melamines, and ureas. All these are thermosetting and under the influence of heat and pressure they become fluid. The fluidity is of limited duration because the heat causes a chemical reaction which converts the resin from a fusible to a non-fusible state.

All the resins of this group contain fillers, the most common of which are cellulosic in nature. The filler for a specific plastic is selected with a view toward the properties desired in the finished material. Wood flour is one of the most commonly used fillers. It is low in cost and the lignin type of material contained in it has a plasticizing effect on the molding resin, permitting the use of relatively high percentages as filler. Where pastel colors are required a refined cellulose is likely to be chosen for filler. For resins with high strength the filler may be fibrous materials, chopped yarns, or macerated fabric. To achieve best electrical properties the filler may be glass fibers, mica or asbestos. High-pressure resins are available in powder, granular or pellet form, in a wide range of colors and in a wide range of plasticities.

Compression molding is usually done in heated metal molds. In the mold under the influence of heat and pressure the molding compound (resin+filler+plasticizer+mold lubricant+catalyst) fuses and flows throughout the mold. The heat causes a chemical reaction in the resin which converts it to a useful hard state.

To change the mold and to remove the molded plastic piece, the mold is made in two sections. The female part of the mold is usually called the cavity, while the male part is described as the force or plunger. Guide pins are used to insure proper alignment of the force and cavity as the mold is closed.

Plastic parts are usually designed so that there are no undercuts on the molds. Undercuts can be molded, but to remove a piece from an undercut cavity requires a split cavity, which can be molded, but which slows production to such an extent that it is used only in extreme cases. Molded plastic pieces are usually removed from the mold by ejector pins acting through the bottom of cavity on the bottom of the plastic piece. Another method involves the use of a stripper plate which acts under the horizontal flash as the press opens, lifting the plastic piece part way out of the mold.

Pressures involved in conventional high pressure molding range from 1000 psi to several tons per square inch. Such pressures necessitate the use of heavy presses which may be operated by hydraulic systems acting on the press ram at pressures of 1 to 2 tons per square inch. The use of low-pressure resins permits molding pressures of 5 to 100 psi. This allows a sizeable reduction in the weight of the press and makes practical the use of water, air, and oil cylinders operating at pressures of 50 to 200 psi on the ram.

The use of low-pressure resins reduces the stresses on the molds, and consequently they can be made of lighter materials. Sheet-metal molds have been used for compression molding of low-pressure resins. However, even though the sheet metal molds are sufficiently strong to withstand the stress involved in molding, heating considerations may dictate the use of heavier molds.

Any of several methods may be used to furnish a heat source. Strip heaters and jackets heated by hot air and hot liquid may be used to heat cavities with thin side walls. Steam has been used most universally in high-pressure molding because of its low cost, availability, and ease of control. For short runs used to obtain

molding data, hand molds are often used. These hand molds may be heated with steam or consist of electrically heated platens in a press. A sketch of a mold cavity heated in this manner is shown in Figure 23. To insure proper heat near the top of the mold it is

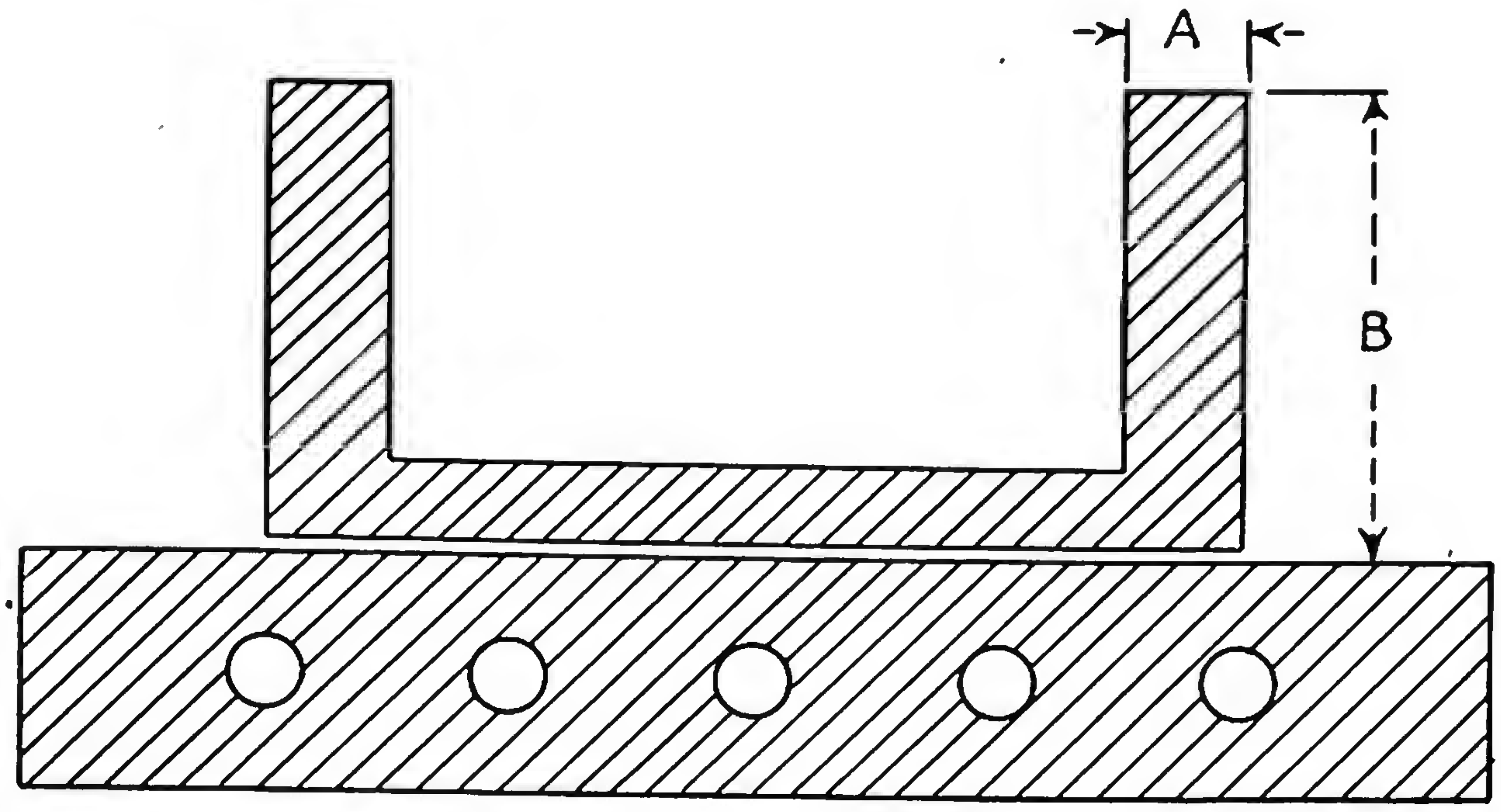


FIGURE 23. Mold cavity. A, width or thickness of the sidewall; B, height of the mold.

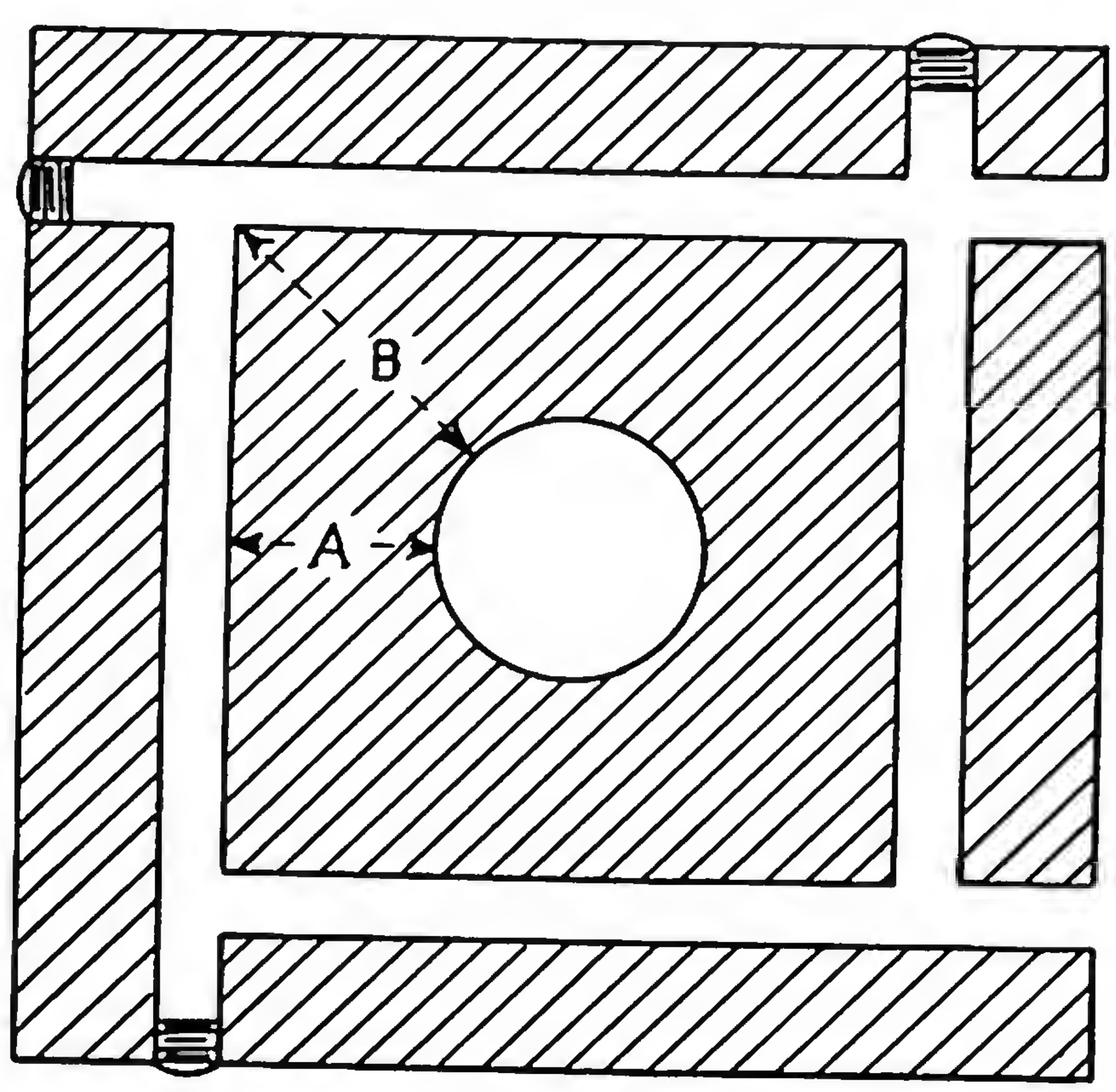


FIGURE 24. "Coring" of a mold for internal heating. A, shortest distance from the cavity to the coring; B, longest distance

necessary to have a fairly thick sidewall. The ratio of the width "a" to the height "b" controls the uniformity of the heat.

For production work, the molds are usually cored for internal heating by steam and mounted on the platens of the press. Figure 24 shows an example of internal coring. The coring should be designed so that the ratio of the length "a," representing the shortest distance from the cavity to the coring, to the length "b," repre-

senting the longest distance from the cavity to the coring, should be ½ or more. Observance of this rule of thumb generally excludes the possibility of cold spots anywhere on the cavity.

When internally heated molds are mounted in a press they are usually insulated from the press to prevent excessive heat losses through the press and to keep the excessive heat from affecting the packing around the press ram. If space permits, the mold may be mounted in a press with asbestos board or spaced metal bars as separators. The mold attached to the moveable platen of the press is connected to the steam source with a flexible steam hose or with a patented angle-joint pipe connection.

Presses are used as a convenient method of opening and closing molds and of applying pressure to the plastic in the mold. The most common type of press has a fixed platen and a movable platen; it may also have one or more intermediate platens which are governed by the rising or falling of the movable platen. The latter is moved by a ram, usually actuated by water or oil pressure. In most cases the ram moves in a vertical plane, and usually the cylinder is located in the bottom of the press so that the bottom platen is the movable platen. In some cases the actuating cylinder is located at the top of the press. When the cylinder is located in the base of the press, the weight of the bottom platen is usually sufficient to open the press at the end of the molding cycle. However, when the actuating cylinder is located at the top of the press, additional cylinders (called pull back cylinders) are required to open the press at the conclusion of the molding cycle.

Presses vary widely in the amount of attention required by the operator. On one extreme are the presses with hand-operated opening and closing valves. Some press operations are automatic, and in these the operator is only required to keep a hopper filled with molding compound.

Three distinct types of molds are available for compression molding.

(1) Flash type mold (Fig. 25).
(2) Positive type mold (Fig. 26).
(3) Semi-positive type mold (Fig. 27).

Flash Type Molds are used to a limited extent in high-pressure molding. To maintain pressure on the plastic while it is curing, it is necessary to pre-densify the molding compound to a high

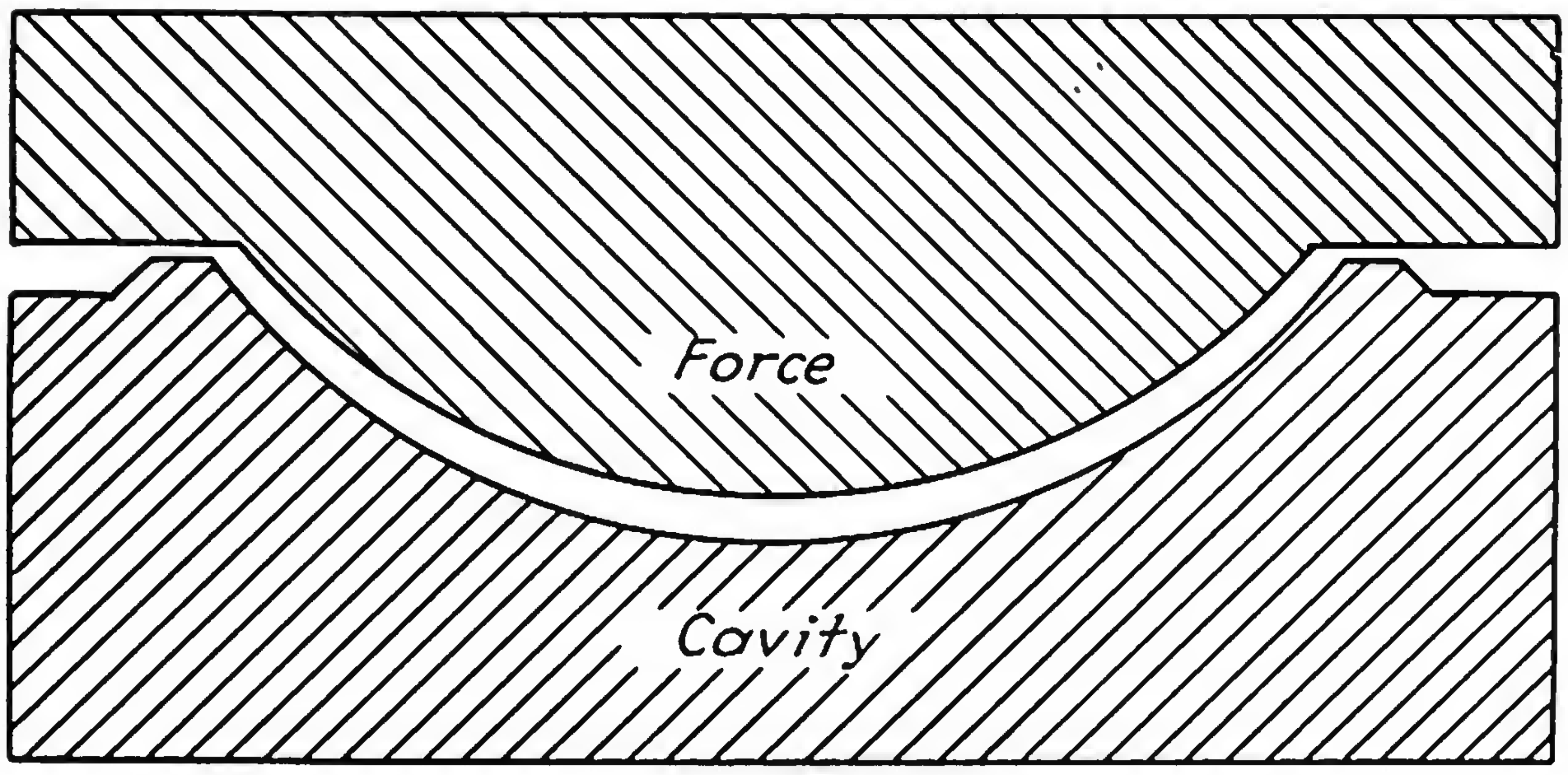


FIGURE 25. Flash type mold.

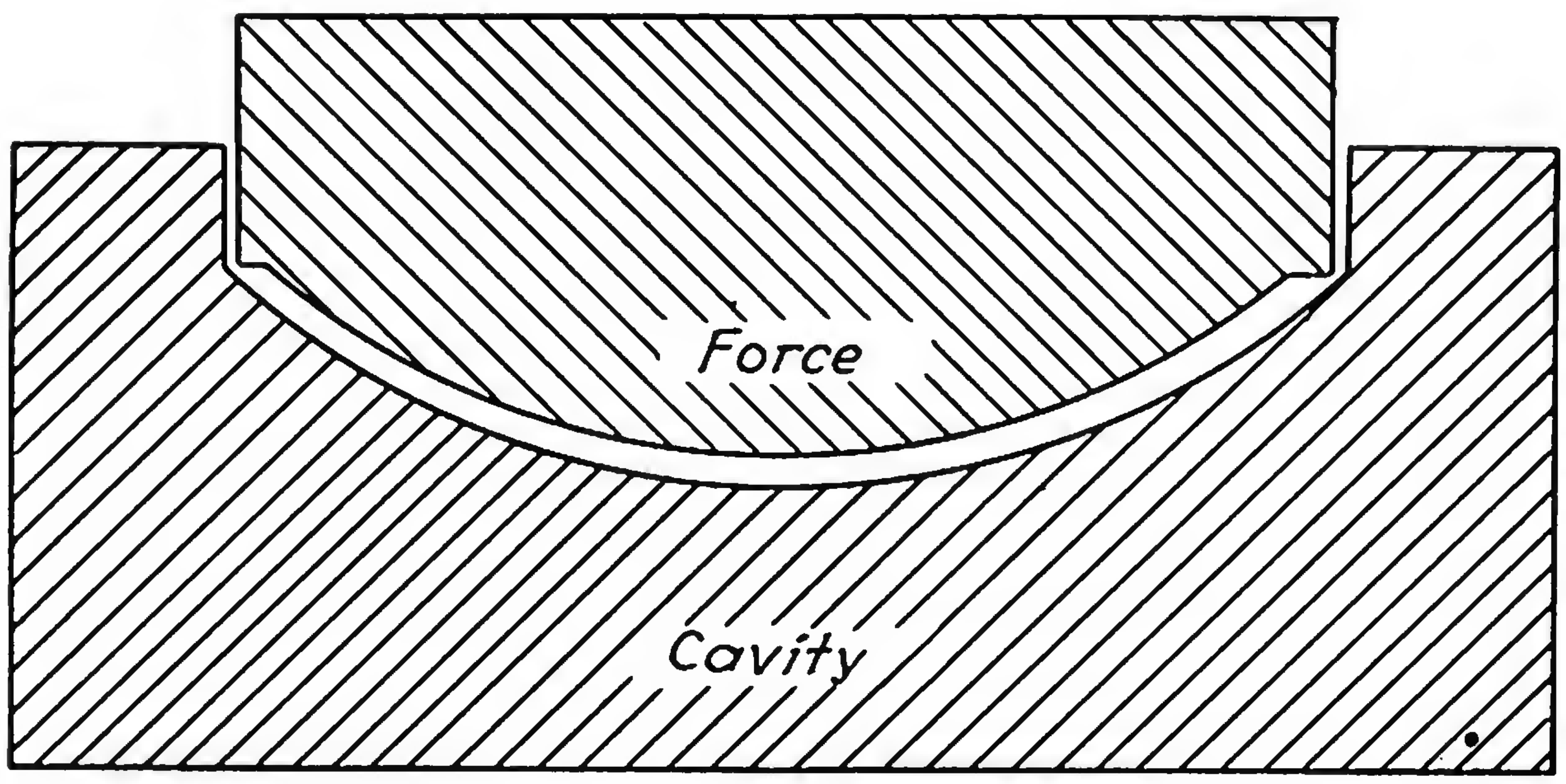


FIGURE 26. Positive type mold.

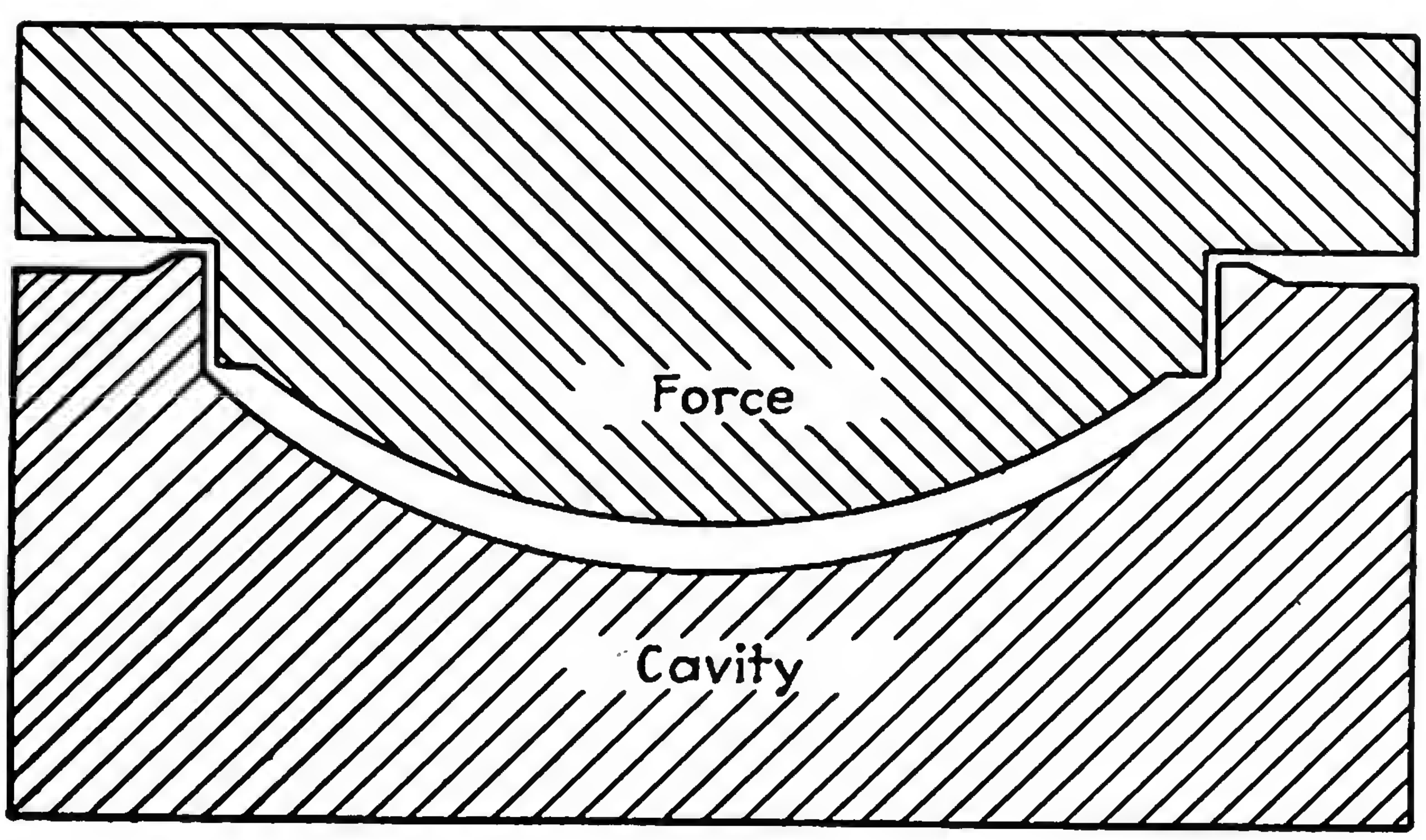


FIGURE 27. Semi-positive type mold.

degree and to charge the mold with a large excess of material. This procedure leads to excessive flash, which is to be avoided because of the wastage. The extremely high shrinkage (10 to 15 per cent) of many of the low-pressure resins tends to limit their use in this type of mold because of the difficulty of maintaining pressure.

Positive Type Molds are designed so that the force is movable during the curing and contraction of the resin. This full pressure is to be applied to the plastic throughout the cure.

Figure 26 is a schematic illustration of the construction of a simple positive type mold. The mold is designed with a minimum amount of clearance between the force plunger and the cavity. During the cure, resin flows into this clearance, but since the clearance is small, this resin sets up quickly and the vertical flash forms a pressure-tight seal.

The amount of molding compound going into this type of mold must be measured with a fair degree of accuracy. Variations in the amount of molding compound produce comparable variations in the thicknesses of the molded plastic pieces.

Semi-Positive Type Molds combine features of the flash type and the positive type molds. Figure 27 is a typical example. A vertical flash and a horizontal flash are combined to give a mold that will maintain some pressure on the plastic throughout the curing cycle, as well as flash out the excessive material of an overcharge.

Low-pressure resins can be used with any of these three types of molds. However, because of the high shrinkage of low-pressure resins during cure and the attendant difficulty of maintaining pressure on the plastic during cure, the positive and semi-positive types of molds are preferred to the flash type.

The advent of low-pressure resins has made possible new techniques. Some low-pressure phenolics and modified urea resins were available several years ago. These resins could be used satisfactorily for laminating in the 50 to 100 psi range. In practice, the resin would be applied to the reinforcement or filler (usually cloth) advanced to a "B" stage (partially set, but not fully cured) and used in this form. Most of the war uses of these materials have been molded by rubber bag techniques which are discussed elsewhere.

The more recent availability of the contact-pressure resins has made possible other molding techniques. Many of these contact-pressure resins are of the modified alkyd type. They are unsaturated and pass from the uncured to the cured state by polymerizing, without the evolution of volatile materials. These resins are available in a range of viscosities ranging from the fluidity of water to the consistency of lard. This high degree of fluidity is adaptable to techniques that are not readily used with the higher-pressure resins.

The techniques for compression molding with contact-pressure resins have not advanced to a state comparable with those of high-pressure molding. Use of contact pressure resins in compression molding, therefore, will probably be limited to the applications where they contribute some property not readily achieved by other methods. This means that by using high-strength reinforcements, plastic products can be applied where older types would not be satisfactory. Some of the properties which might justify the use of contact-pressure resins are:

(1) High strength
(2) Special finishes
(3) Special electrical properties
(4) Dimensional stability

High Strength. Compression molding compounds are designed so that the molding compound flows freely throughout the space between the cavity and force during the molding cycle. To attain this degree of fluidity, it is necessary to use a filler that will flow with the resin. When this degree of fluidity is achieved, short-fibered materials such as wood flour and alpha-cellulose must be used as the filler for the resin.

The use of contact-pressure resins allows the resin and the filler to be added to the mold cavity separately. Thus the filler (or reinforcement, as it is more commonly called when used with low-pressure resins) for the resin can be preformed to approximate the shape of the mold cavity. This permits molding of the plastic piece with minimum movement of the reinforcement; consequently, high-strength reinforcements such as cloth or mats may be used. Of all the strength properties, impact will probably account for most of the changes from high- to low-pressure molding, since the

impact strength of mat- or cloth-reinforced plastic is usually many times that of high-pressure molding compounds.

Methods of Preforming. In general, molding cycles are slowed somewhat when mats or fabrics are used as reinforcement. As the use of this type of molding becomes more widespread, it is likely that molding cycles will be shortened by improvements in the curing characteristics of resins, by the use of specially designed reinforcement materials, and by improved techniques.

A method now used to speed up molding cycles is preforming the reinforcement. Cloths are readily adapted to drawing methods which involve the slip-ring soft-plunger techniques described later. Knit fabrics and specially woven cloth are available and ideally suited to this process. However, most cloths are not as well suited to preforming as are mat products.

Mat products may be held integrally together by felting, by interlacing, or by resinous binders. Their forming characteristics depend largely on the orientation of the fibers, and their preforming characteristics (ability to retain a formed shape) will depend largely on the means employed to hold the mat together. Mats bonded with a thermoplastic resin can be preformed under the influence of heat and will retain the preformed shape when returned to room temperature. When "B" stage thermosetting resins are used as the bonding agents, the mat can be formed; and if heat is used in the preforming operation, the resin will be cured and the mat will retain the preformed shape. When "C" stage (fully cured) thermosetting resins are used for bonding, the mats will probably be sufficiently strong to stand rough handling. However, the mat will probably have poor drawing characteristics.

Mats having a random pattern of fibers usually draw better than mats with straight fiber orientation. The severity of any specific draw is controlled by the ratio of the depth of the cavity to its breadth. In preforming areas such as the corners of a box, excessive localized stresses may result. This shows up as thinning out of the mat, and in extreme cases the mat may break. Thinned out areas may be strengthened by adding small patches of the mat to the preform.

Mats may be preformed by one of the following methods:

(1) The mat may be pressed between two mating dies.

(2) The mat may be formed against a die, using fluid pressure.

A vacuum diaphragm or a flexible diaphragm backed up with fluid pressure may be used.

Heat can be used in any of the above steps if the nature of the mat warrants. The dies for these preforms can be made of rough castings of metal, concrete, wood, plaster, or other materials.

Fibrous materials such as alpha-cellulose, asbestos, cotton, glass fibers or unbleached kraft may be dispersed in water and vacuum-felted onto a preformed metal screen. While the art of pulp molding is old, its application in the plastic industry is rather recent. Where culluosic materials are to be employed as reinforcements, a paper beater is used to produce the desired fiber length and degree of hydration. For high-pressure molding, powdered phenolic resins may also be added to the beater, together with suitable coagulants to cause the powdered resin to adhere to the cellulose fibers. The contents of the beater are transferred to a tank and diluted to a consistency of ½ to 1 per cent solids. The fibers and resin are vacuum-felted onto a preformed metal screen, which approximates the dimensions of the mold. The preform is dried to remove the excess water, and is subsequently molded under heat and pressure.

Reference

U. S. Patent 2,365,331 to W. W. Carter, Dec. 19, 1944.

Where contact-pressure resins are to be used, the procedure is modified. Only the fibers and the chemicals required for dispersion are added to the tank. A fiber preform is made and dried, and the resin may be added to the preform by means of a solvent, or the resin and preform may be put in the mold separately.

The screens for the preforming may be made of 60- to 80-mesh brass wire screen. This may be backed up by perforated sheet metal. The brass screen can be deformed to fit over mild compound curvatures. On more difficult shapes, the screen can be cut and the cut edges soldered.

This method of preforming will normally produce a preform of fairly uniform thickness. If the thickness in any area tends to build up excessively, the resistance to flow of the liquid through this area increases, thereby decreasing the rate of liquid flow and consequently the rate of fiber deposition in this area.

Pulp preforms are felted and have considerable strength for handling. However, the preforms are bulky, and consequently

are best suited to shapes that can stand a fairly high compression ratio in molding. In production, a tank is inserted in the vacuum line, and fresh water used as make-up. For safety, the vacuum pump should be one which will handle water as well as air.

A preform made of a high-strength reinforcement by any of these methods can be molded in any of the three types of molds: positive, semi-positive, and flash. A measured amount of resin can be poured into the heated mold, the reinforcement added, and the mold closed. Or the preform may be saturated with resin before it is placed in the mold cavity. In some instances the dry preform is placed in the mold cavity, the cavity closed and a liquid resin injected into the preform. The resin will enter at one or more low points in the mold, and the mold will be vented at the top so that the resin can displace all the air trapped in it.

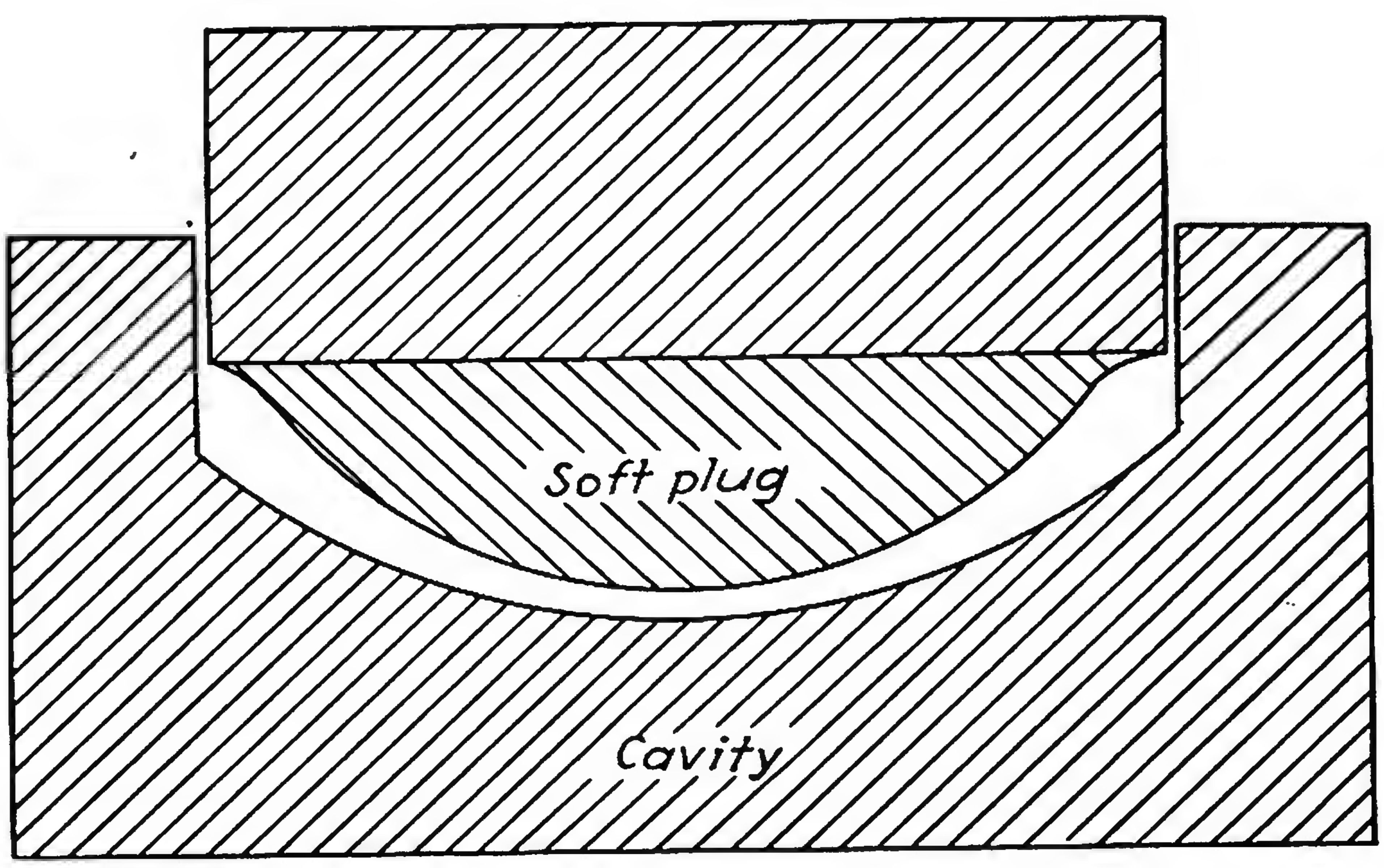


FIGURE 28. Combination heated metal cavity mold with a soft plunger.

The combination of low-pressure resins and high-strength preforms is particularly well adapted to another type of molding—one which combines the use of a heated metal cavity with a soft plunger. Figure 28 shows the operations schematically. Usually the mold will be mounted in a press that will permit quick opening and closing and that will supply molding pressures in the range of 15 to 100 psi.

The soft plunger does not usually follow the contour of the female mold. When the resin is poured into the mold and the preform added later, the biggest problem encountered is achieving complete

removal of air from the laminate. Consequently, the contour of the soft plunger is not necessarily the same as that of the cavity. Flat areas are rounded and corners exaggerated so that as the mold closes in the molding operation, the plunger strikes the lowest point first and works progressively outward and upward. This technique moves the air and resin progressively outward and upward, as the reinforcement preform is compressed by the soft plunger, resulting in an air-free plastic piece.

Pin hole-free laminates are desirable. Holes arise from one or both of two basic sources:

(1) air occluded in the resin or reinforcing agent, or
(2) gases formed during curing.

Occluded air in resin may be removed by letting the product stand for a time after the catalyst has been incorporated. Air in the reinforcing agent may be removed or minimized by evacuating the impregnating chamber to 23″ to 28″ vacuum, after which the bubble-free resin is admitted to form the combination to be used for the lay-up. Use of a hand roller will help eliminate trapped air from several plies of uncured laminate. Other methods may be used to accelerate removal of entrapped air from the laminate.

Gases may be formed during curing by use of an air-sensitive resin, by too low a curing pressure to keep the gases in solution, or by too fast a curing cycle for the gases formed to be removed by ebullition or by vacuum. Use of a resin which does not form bubbles at the curing temperature and pressure used is essential. Care in mixing, lay-up and curing steps should then make possible the production of a pin hole-free laminate.

When a soft plunger type of mold is used, the outside surface of the molded plastic piece will be smooth, duplicating the mold surface. However, the inner surface may be somewhat irregular because the soft plunger gives a fluid type pressure. However, because of this, it is possible to achieve stronger reinforcement than with metal force molds. The thicker areas in soft plunger moldings are caused by thicker reinforcement in those areas. A metal force concentrates the molding pressure in these thicker sections, and an excessive concentration of pressure may actually crush the fibrous reinforcement. In less extreme cases, the excessive concentration of pressure may cause the thicker sections to move slightly, thinning the reinforcement in other portions and creating an area of weak-

ness. With a properly designed rubber plunger there need be no movement of the reinforcement other than that occurring in the inner fibers when the preform is expanded against the mold. Irregular thickness in a molded plastic piece tends to cause warpage in large flat areas, particularly if the piece is thin. On thicker pieces and on symmetrically curved pieces, variations in thickness usually produce no bad effects.

For some shapes the reinforcement is formed in the mold cavity as the first step of the molding operation. A slip ring is mounted on the top of the mold outside of the cavity; the reinforcement slips between the ring and the mold as the force enters the cavity. This operation is shown in Figure 29. The slip ring provides a

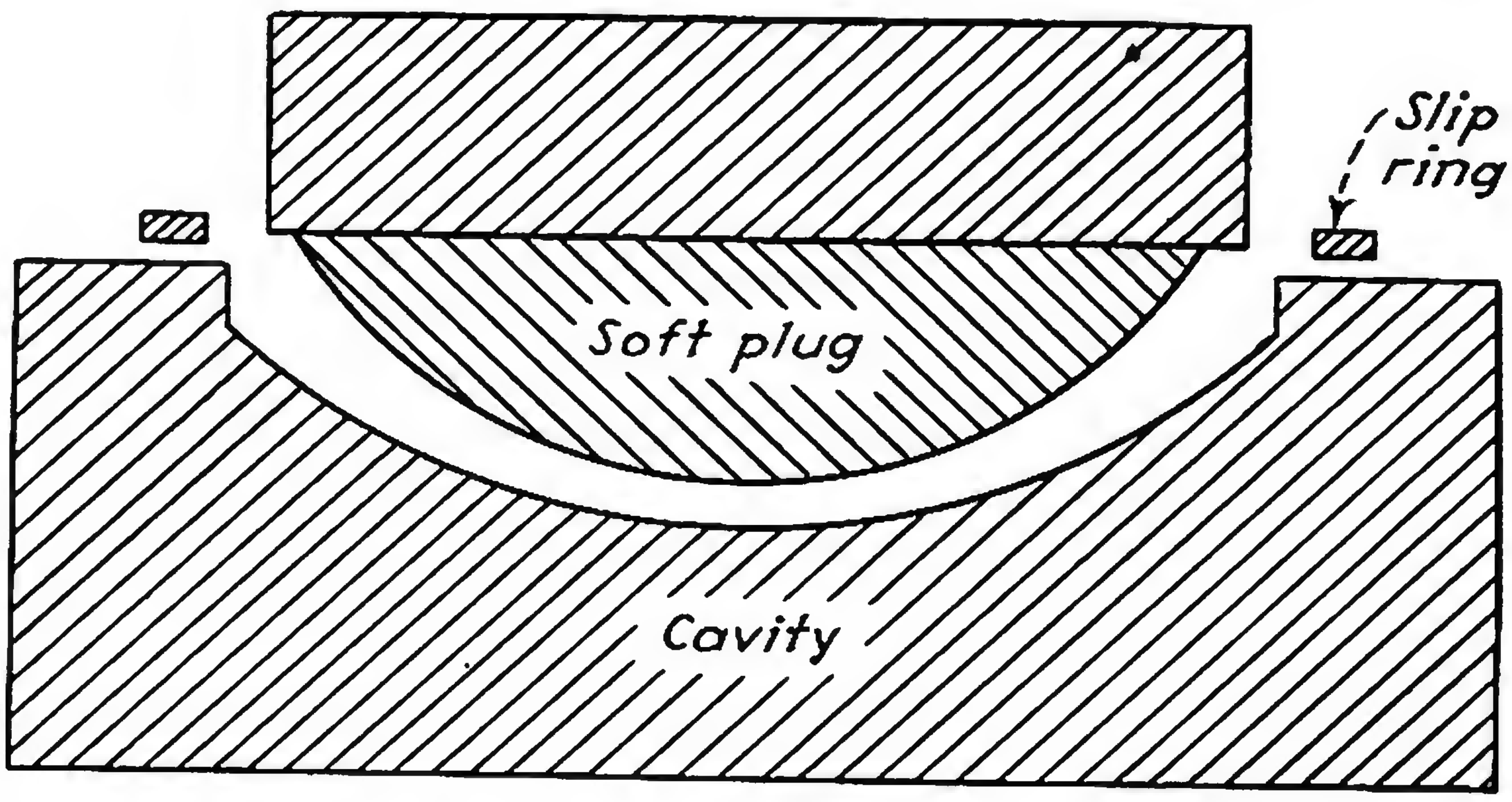


FIGURE 29. Use of "slip-ring" to facilitate preforming of reinforcing material within a mold.

slight restraining action so that the reinforcement is formed in the cavity without wrinkling. To form the corners on the sides of a box-shaped piece, additional restraint on the reinforcement is required at the corners, and this can be provided by using "fingers" in the corners.

Cloth is ideally suited for this type of operation, provided that the draw is not sufficiently drastic to require cutting. Knit fabrics can be used for extreme draws. Woven cloths especially designed for good drawing characteristics are available.

If a low-pressure phenolic resin is used for this slip ring operation, the cloth or mat will be impregnated and advanced to the "B" stage on the reinforcement. If a contact pressure resin is used, it can be poured into the mold or applied to the reinforcement in advance of the drawing operation.

A few of many patents of interest to laminating are cited in the following paragraphs.

U. S. Patent 2,308,453 to J. A. Potchen and O. H. Basquin, January 12, 1943. "Apparatus for Manufacturing Laminated Material." Uses a light weight or thin die for shaping plywood and other moldable materials, a flexible, fluid-impervious cover, means for securing said cover as with metal clamps, and then placing the whole assembly in an autoclave for curing under pressure.

U. S. Patent 2,329,425 to C. H. Steel, September 14, 1943. "Molding Apparatus." Provides a clamping means for a molding apparatus which will compensate for expansion or contraction of the reinforced plastic as well as for the softening of the rubber member. A resilient member is included in the clamping arrangement.

U. S. Patent 2,357,392 to C. S. Francis, Sept. 5, 1944. "Process For Producing Fibrous Products." A felted fibrous product is produced by dispersing the fibers in a chamber, gathering them on a flat chain belt in combination with a binding material.

U. S. Patent 2,363,107 to S. H. A. Young, Nov. 21, 1944. "Expandable Plastic Mold." An apparatus for molding plastics has a heated bottom die. A second die is moved vertically by a power cylinder and contains an expandable member for directing fluid pressure against the mold cavity.

U. S. Patent 2,370,429 to Eugene L. Vidal, Feb. 27, 1945. "Laminated Structure and Method for Making Such Structure." A laminated boat hull is made by using fluid pressure to bind the sheets and strips into a structural unit.

U. S. Patent 2,372,983 to Henry M. Richardson, April 3, 1945, "Spinning Bucket." A reinforced plastic spinning bucket contains glass yarn running circumferentially through the walls in the direction of the principal stress. An acid-resistant phenolic resin is recommended.

U. S. Patent 2,373,033 to Karl J. Kopplin, April 3, 1945. "Smooth Surface Fibrous Article." A fluffy mat material, such as sisal, is laminated and compressed together with a resin for cure. The resin is concentrated near the surfaces to product a smooth sheet.

U. S. Patent 2,376,805 to R. W. Peacock, May 22, 1945, "Molding Apparatus." An improvement in mold assemblies to provide better evacuation and less clogging of vent lines with molding resin or filler or other evolved material such as gases. Metal clamps are used.

U. S. Patent 2,378,642 to K. J. Kopplin, June 19, 1945. "Process of Making Fiber-Body Articles." A loose unwoven mat of long fibers is formed in a hollow die. The mat is loose enough to permit slippage without breaking the fibers. A binder is applied and then cured.

U. S. Patent 2,388,184 to K. E. Ripper, Oct. 30, 1945. "High Strength Laminated Amino Plastics." A thermosetting amino plastic resin such as melamine-formaldehyde is used to bind sheets of paper and sheets of glass cloth into a rigid laminated article.

It is appropriate at this point to mention that countless man-hours of work are lost to American industry because of ineffective measures used to combat and control annoying distracting skin afflictions, often due to handling materials mentioned in this chapter. Occupational dermatitis has been credited by Public Health authorities as responsible for the loss of 6 million man-days lost to industry each year.

One material called "Ply No. 9" is recommended for protection against explosives, coal tar derivatives (phenol, cresylic, formaldehyde) and severe hydrocarbon solvent hazards. This liquid is rubbed into all exposed skin areas to complete dryness. It can later be removed with mild soap and warm water. This product is supplied by:

The Milburn Co., 3246 East Woodbridge St., Detroit 7, Mich.

Two other materials for treating and controlling dermatitis and dermatoses of external origin are supplied by:

Tenex Laboratories, Inc., Cedar Rapids, Iowa.

Tenex Liquid is supplied for treatment as directed by a physician. It contains the active ingredients: chlorthymol, menthol, thymol, phenol, benzocaine, oil of wintergreen, salicylic acid and benzoic acid.

Tenex Tar Cream forms a therapeutic, protective film against irritants. Its active ingredients are: chloesterin, lanolin, menthol, benzocaine and carbonis detergens in greaseless cream base.

Ever important is the need for compatibility of various ingredients being cured to form a laminate. The resin binder on the reinforcement must be compatible with the resin used for laminating. Some foreign ingredient can often be the troublesome factor, by disturbing the complicated physico-chemical equilibrium involved in the curing cycle. Let us turn to a consideration of some reinforcing materials which may be used in low pressure laminates.

Chapter 4
Reinforcements for Plastics and Sandwich Structures

By *filler* is meant some material added to a resin which usually contributes little, if any, additional strength properties. Wood flour has been used in plastics for that purpose for many years. Chiefly, such a material serves as a *diluent* to lower the cost per pound of the molding composition and yet not impair the strength of the merchandise too much.

The term *reinforcing agent,* designates some material which enhances the physical properties of the resin alone. Such properties include tensile strength and flexural strength.

Reinforced laminates are used in many varied fields and for many purposes such as:

Automotive uses
Aviation industry
Chemical industries
Decorative applications
Factory truck wheels gears
Industry and radio industry
Marine industry paper
Process industries
Steel industry
Telephone industry
Textile industry
X-ray and therapeutic apparatus

Some fabricators of such reinforced laminates are :

Formica Insulation Co., Cincinnati, Ohio.
Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.

Note: Also see list of laminators given in Chapter 1 under the section on "Post-forming." The number of laminators and fabricators is constantly increasing. See reference books cited at end of Chapter 1 for further details.

Asbestos

Asbestos fabric or mixtures with paper, cotton or glass are often used to fabricate laminates, especially used in the electrical industry. Sheets, tubes and rods are furnished in many different grades to fulfill the requirements.

Average physical strength values for such laminates are:

Tensile strength	8,000-10,000 psi
Flexural strength	15,000-20,000 psi
Compressive strength (flatwise)	35,000-40,000 psi

Such reinforced laminates are used for:

Armature slot wedges.
Wedges in railway and mill motors transformer coil spacers.

Better impact strengths are obtained in laminates by using longer asbestos fiber. Shorter grades of asbestos give a better surface finish to molded plastic parts. Careful handling of the fibers is required during resin impregnation in order to retain full strength. Asbestos paper base and asbestos cloth base have been used in laminated plastics.

The heat resistance of plastics containing asbestos fillers is greatly increased. Continuous use over a temperature range of 375 to 400° F is possible. Intermittent operation up to 500 to 525° F may be practiced. No wood-filled material can withstand temperatures in this range.

Special grades of asbestos, free from iron or other electrically conductive materials, must be used for good dielectric properties.

Asbestos-filled plastics have good chemical resistance to moderate concentrations of both acids and alkalies as well as to mild oxidizing agents.

Much asbestos is mined in Canada and is graded in seven groups as follows:

Group No.	*Name*	*Approx. price per ton (2000 lbs.) f.o.b. mine*
1	Crude No. 1	$725.00
2	Crude No. 2; crude run-of-mine and sundry	300.00
3	Spinning or textile fiber	150.00
4	Shingle fiber	75.00
5	Paper fiber	45.00
6	Waste, stucco or plaster	31.00
7	Refuse or shorts	20.00

Vermont material is graded into five groups: "shingle," fiber, paper stock fiber, waste, shorts, floats. Prices are comparable with those quoted above.

References

"Cold Molding Compounds," by Emile Hemming, *Modern Plastics*, page 34 (October, 1939).
"Asbestos in Plastics," by R. L. Fine, *Asbestos*, page 3 (February, 1941).
"Molded Electrical Insulation of Asbestos Cement," by S. Pellerano and Chas. W. Gardner, *Asbestos*, page 4 (July, 1941).
"Asbestos in Plastics," by M. E. Lerner, *Asbestos*, page 10 (December, 1942).

Asbestos may be obtained from the following suppliers:

Asbestos Corp., Ltd., Thetford Mines, Quebec, Canada.
Connell Asbestos Mfg. Co., 165 Clymer St., Brooklyn, N. Y.
Johns-Manville Co., 22 East 40th Street, New York 16, N. Y.
Phillips Asbestos Mines, P. O. Box 662, Globe, Arizona.
Southern Asbestos Co., Charlotte, N. C.
The Quebec Asbestos Corp., East Broughton, Quebec, Canada.
Union Asbestos & Rubber Co., 1821 54th Ave., Cicero, Ill.
Vermont Asbestos Mines, Eden, Vermont.
Whittaker, Clark & Daniels, Inc., 260 West Broadway, N. Y.

Cotton

Cotton fabrics have long been used as a reinforcing material in high-pressure laminates for many electrical and mechanical applications. The tensile strength and the thread count of the cotton cloth are carefully controlled. The twist of the yarns and amount of sizing used are also specified in order to produce the qualities desired in the laminates.

Duck fabrics of heavy weave such as counts of 59 x 36 to 49 x 40 and weighing 7.50 to 8.00 ounces per yard are often used as a reinforcing material. Lighter-weight fabrics of 4.00 oz. per yard and up have been used. Cambrics and percales are lighter-weight textiles which are also used.

Phenolic resin laminates with cotton have the following average physical strengths:

Tensile strength	8,000-9,500 psi
Flexural strength	17,000-20,000 psi
Compressive strength (flatwise)	35,000-38,000 psi
Compressive strength (edgewise)	13,000-16,000 psi

For molded parts, chopped pieces of resin-impregnated cloth are formed under heat and pressure.

Non-woven cotton fabric may be used for lamination. In such a

material the costs of weaving are avoided, and in certain instances the irregularity of the fibers and the matter effect are advantageous. Various weights of such non-woven fabric are made under U. S. Patent No. 2,839,312 and called "masslinn." Such material is supplied by:

Chicopee Sales Corporation, 47 Worth St., New York 13, N. Y.

Another supplier of non-woven cotton fabric is:

Avondale Mills, Sylacauga, Ala.

Cotton is used in oriented bats to give high strength and a much lower cost than in the form of cloth. The trend is to use fibers not woven into cloth, in order to achieve lower costs. Cotton flock is also used. Some suppliers of cotton materials are:

Becker, Moore & Co., Inc., 50 Bridge St., North Tonawanda, N. Y.
Burnet Co., 100 Gold St., New York 7, N. Y.
Claremont Waste Mfg. Co., 1935 Elm St., Claremont, New Hampshire.
J. H. Lane & Co., Inc., 250 W. 57th St., New York, N. Y.
Rayon Processing Co. of R. I., 865 Tremont St., Central Falls, R. I.
Wellington Sears Co., 65 Worth St., New York, N. Y.

Impact strength is increased remarkably by the addition of 1 to 5 per cent of *chopped fiber* to any ordinary resin.

Cloth base laminates are used in many applications, which include the following:

Aircraft fair-leads
Ball retainers
Chemical system valve bodies
Gears
Marine switchboard panels
Paper mill doctor blades
Pinions
Piston and packing rings
Pump vanes
Plating barrels
Rod, skelp and bar mills
Steel mill finishing stand bearings
Suction box covers
Terminal boards
Textile mill equipment bearings
Water pump gears
Wet chlorine gas tubing systems

Glass

One of the best known materials for reinforcement of plastics is glass in fiber form manufactured and sold under the trade mark name of "Fiberglas" by the Owens-Corning Fiberglas Corporation, Toledo 1, Ohio.

The combination of Fiberglas and a suitable resin provides an entirely new and different type of product, with a combination of characteristics found in no other material.

Development of Fiberglas-reinforced plastics was given an impetus by wartime requirements and the laminates were put to use in a wide variety of military applications, particularly in aircraft where great strength with light weight were vital. Industry and the consuming public, aware of the recent advances in materials technology, are expecting these innovations in the products they buy. Designers and engineers already are utilizing the advantages of Fiberglas-reinforced plastics in the automotive, electrical, chemicals and other fields.

Fiberglas is glass in the form of extremely fine fibers or filaments having very high tensile strength. Twisted into yarns and then woven into cloths, these Fiberglas fabrics impart their outstanding properties to the finished plastics laminates. The strength per unit of weight of plastics reinforced with Fiberglas cloth is superior to that of commonly used structural materials. Impact strength many times greater than that previously obtained in laminates is being attained through Fiberglas reinforcement. Moisture absorption of these products is as low as or lower than that of pure resins; and Fiberglas-reinforced plastics are as dimensionally stable as metals.

When Fiberglas is used with contact- or low-pressure resins, large, complicated parts can be formed with relatively inexpensive molds, and important time, labor and cost savings are effected.

Thin, porous, web-like mats of fine glass fibers are also available and are used for plastics reinforcement with excellent results. Providing dimensional stability, high temperature resistance, low moisture absorption and good dielectric properties, Fiberglas mat is an economical material for use where the exceptional strength provided by Fiberglas cloth is not required, but where the other basic Fiberglas properties are desirable.

Twelve advantages of plastics reinforcement with Fiberglas have been listed as follows:

(1) High tensile, flexural and compression strengths
(2) High impact strength
(3) Light weight
(4) Low moisture absorption
(5) Dimensional stability
(6) Ease of forming
(7) Fast, low-cost tooling

(8) Electrical and non metallic properties
(9) Low thermal conductivity
(10) Damping properties
(11) Corrosion resistance
(12) High temperature resistance

Glass has been used extensively as a reinforcing agent for plastics. During the war many thousands of yards of glass cloth were used for numerous wartime applications including the following:

Aero cargo container (Figure 30)
Aircraft flooring
Ammunition boxes
Anti-drag ring segments
Bail out helmets
Binocular cases
Cargo liners
Doron armor (Figure 31)
Ducts for Aircraft (Figure 33)
Flak curtains
Flak housing
Fuel cell tanks
Glider nose
Helicopter blades
Helicopter cabins
Instrument housings
Life floats
Map cases
Parachute kits
Phototemplates (Figure 32)
Plastic litter
Propeller blades (Figure 34)
Radomes (Figure 35)
Stabilizer fairings
Tail cones
Tail-gun turrets
Wheel fairings
Wing liners

When Fiberglas cloth is cut, it is desirable to use a sealer to prevent unraveling of the threads.

"Kantfray" is a fire-resistant sealer for Fiberglas cloth and is sold by:

H. I. Thompson Co., 1733 Cordova St., Los Angeles 7, California.

The following varieties of glass materials are offered by Owens-Corning Fiberglas Corporation to the field of low-pressure laminating. Many of the products are still in an experimental stage of development necessitated by the rapid changes being made in the nature of resins, the adoption of improved fabricating techniques, and the needs of the market which finally decides the salability of any product.

Unidirectional Fiberglas Cloths

General properties of the laminate:

High tensile, compressive, flexural, impact and modulus

High temperature resistance
Dimensional stability
Low specific gravity
Corrosion resistance
Low thermal expansion

Recommended uses:

(1) Where maximum strength is needed in laminates.

(2) Where design requirements necessitate a predominance of strength properties in a given pattern.

(3) Where localized strengthening is needed.

(4) Where unidirectional strengths only are required.

Unidirectional Cloths available: X-1968, X-1750.*

		X-1968	*X-1750*
Nominal thickness		9 mils	9 mils
Weight oz. per sq. yd.		8.84	8.5
Approx. break strength (lbs. per inch)			
	Warp	750	60
	Fill	75	735
Standard width		38″	38″

Eight-Harness Fiberglas Cloths

General properties of the laminate:

Same as for Unidirectional Cloths, described on page 64.

Recommended uses of thin cloths:

(1) Where high tensile, compressive and flexural strengths are required.

(2) Where high strength skins are needed for sandwich structures.

(3) Where bidirectional strength properties are required.

Recommended uses of medium cloths:

(1) Where medium high strengths are required along with other inherent properties of Fiberglas laminates.

(2) Where bidirectional strength properties are required.

Recommended uses of heavy cloths:

(1) As core materials in sandwich structures.

(2) Where the inherent Fiberglas properties are required in medium strength parts.

(3) Where bidirectional strength properties are required.

* These X numbers are experimental numbers and are subject to change when standardized.

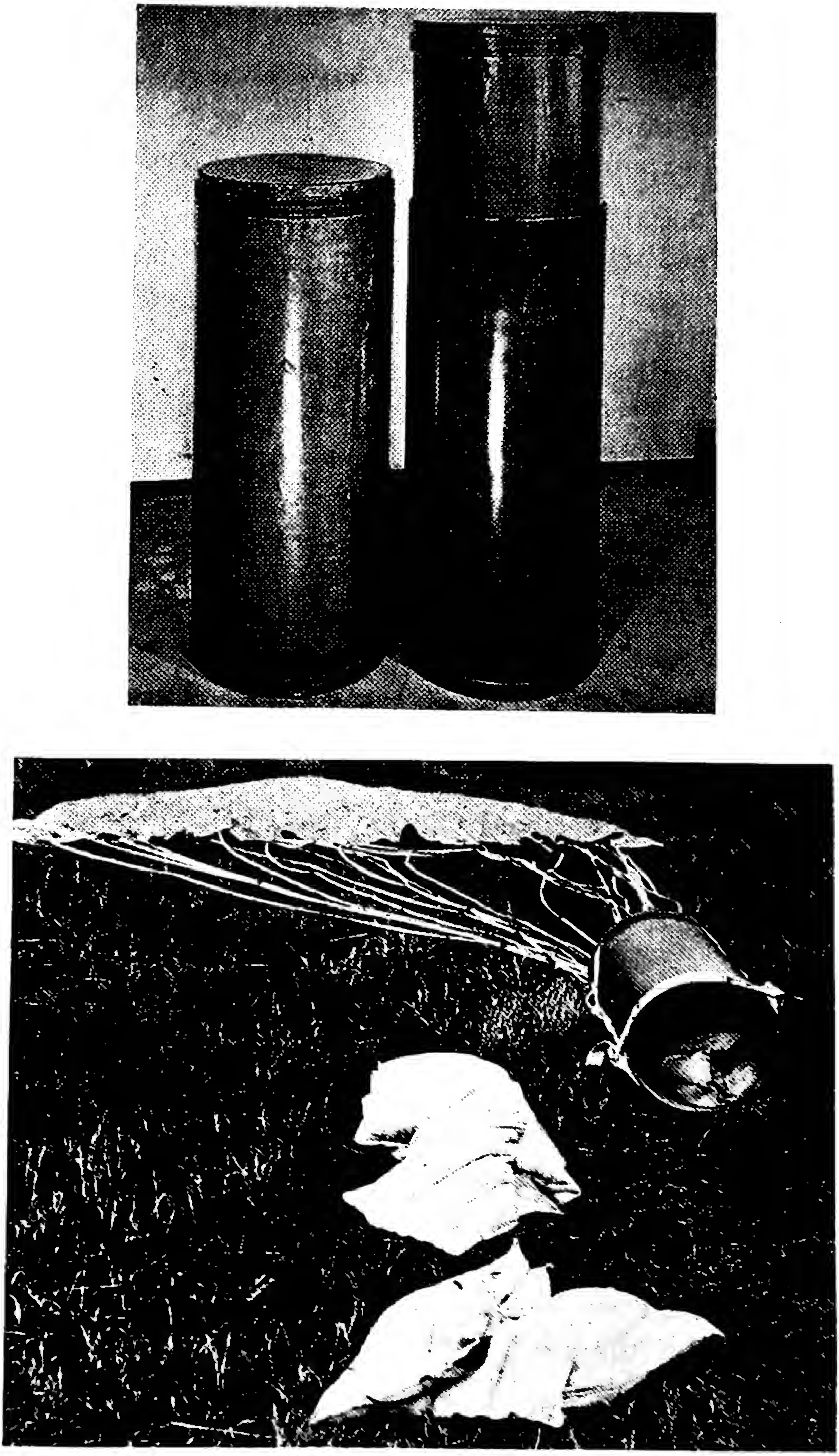


FIGURE 30. Aero cargo containers.

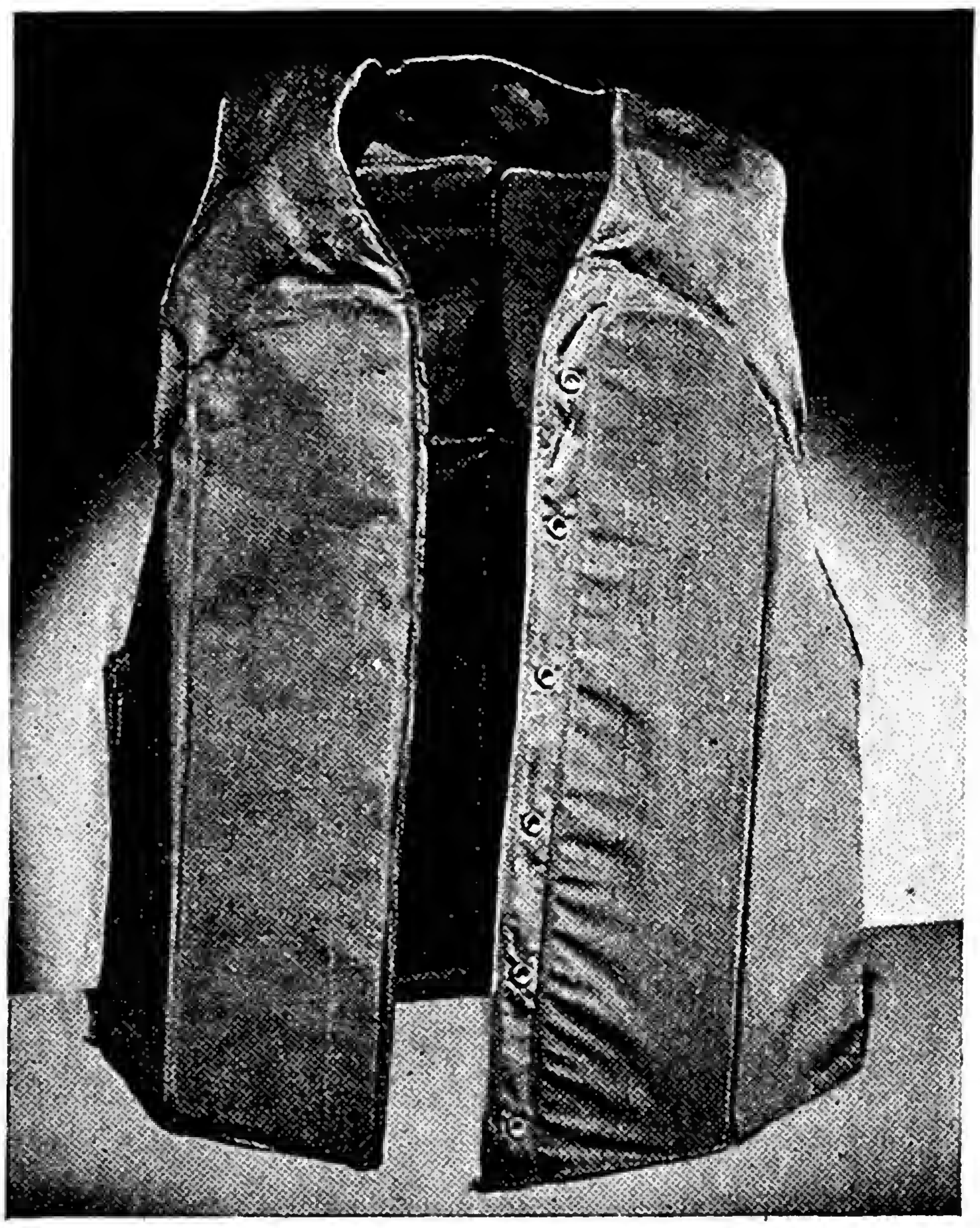


FIGURE 31.

Bullet proof vest equipped with panels of Fiberglas reinforced plastic known as Doron armor.

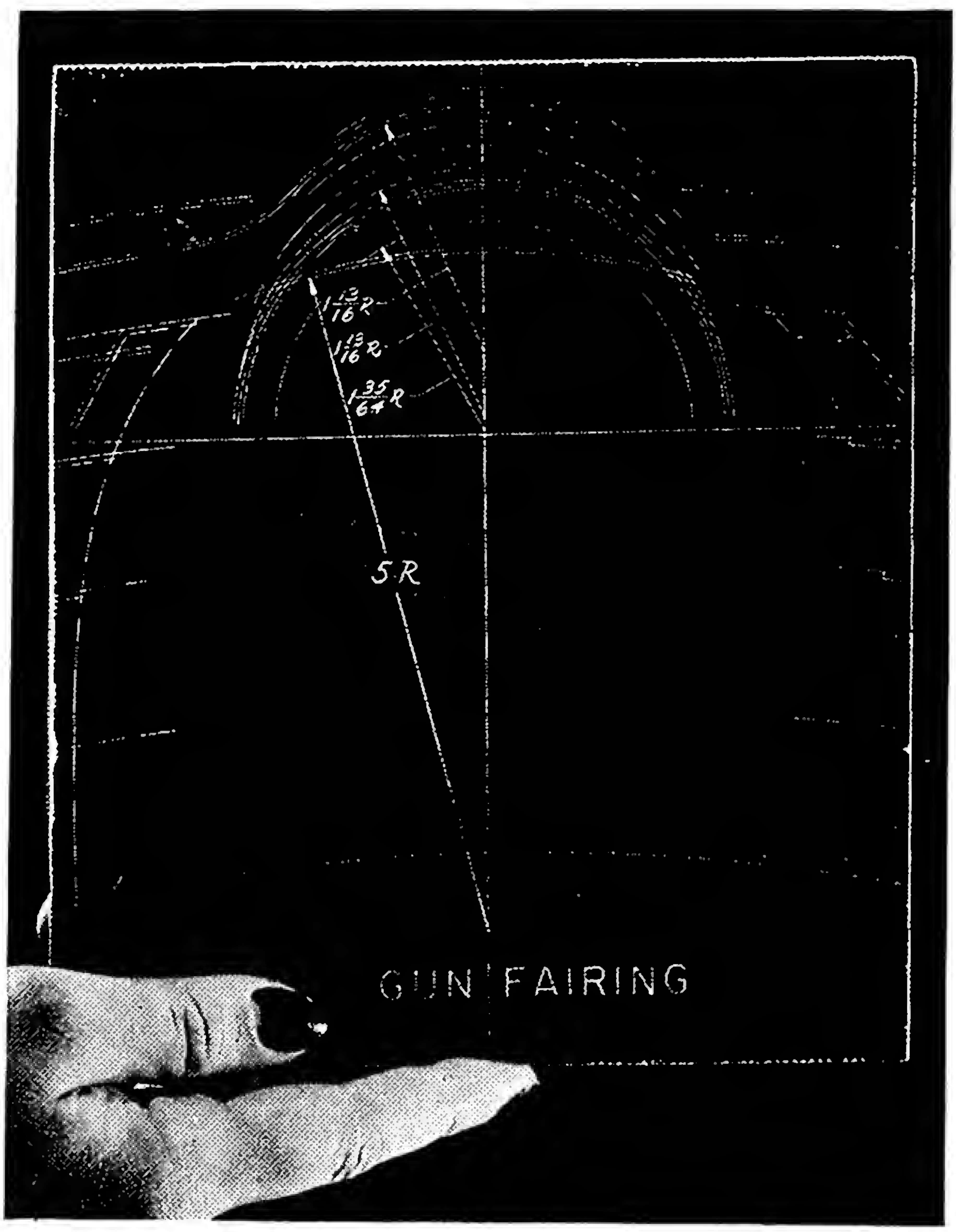


FIGURE 32.

Fiberglas reinforced plastic photo template.

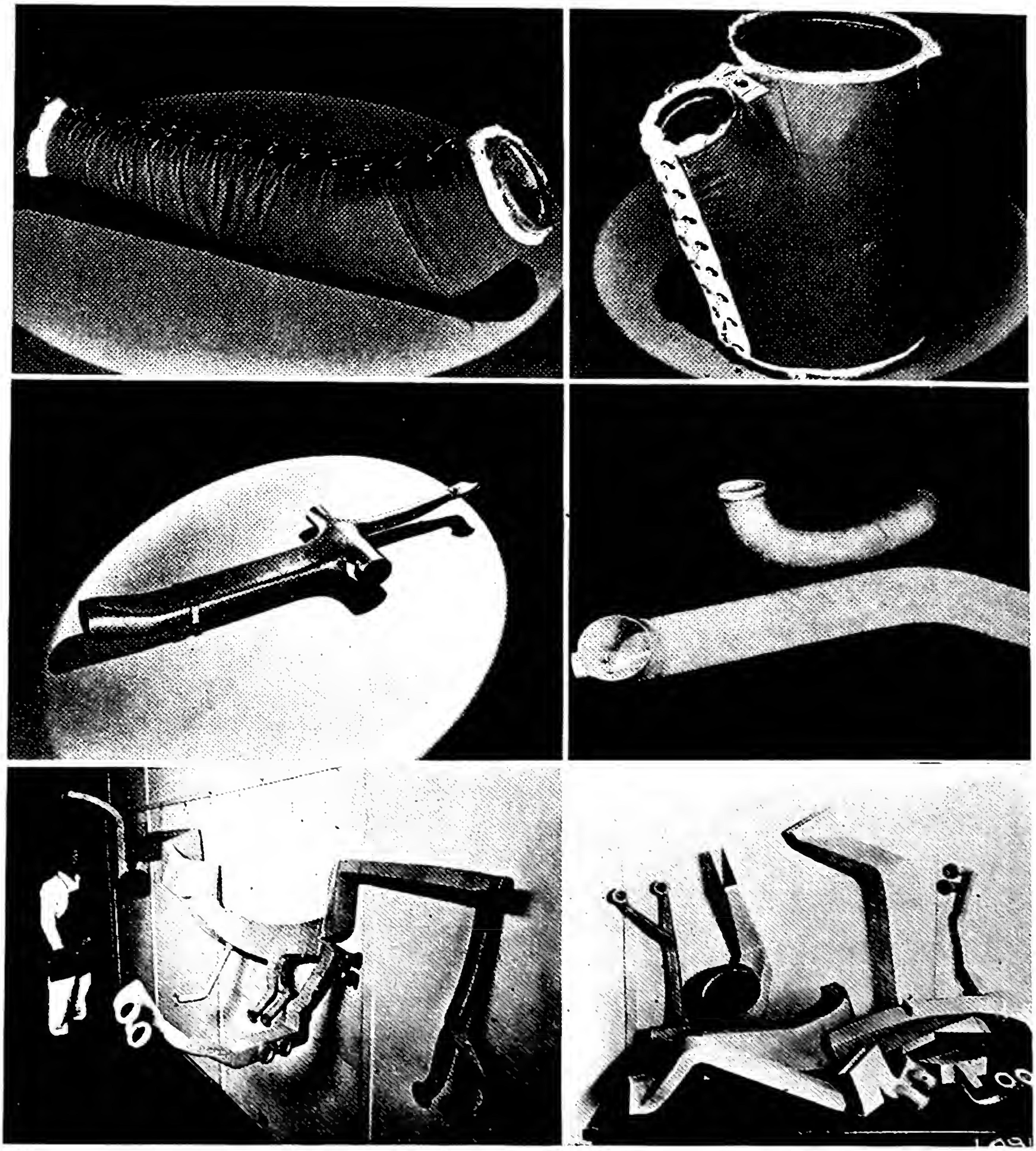


FIGURE 33. Various shaped parts made of Fiberglas reinforced plastics for duct work on airplanes.

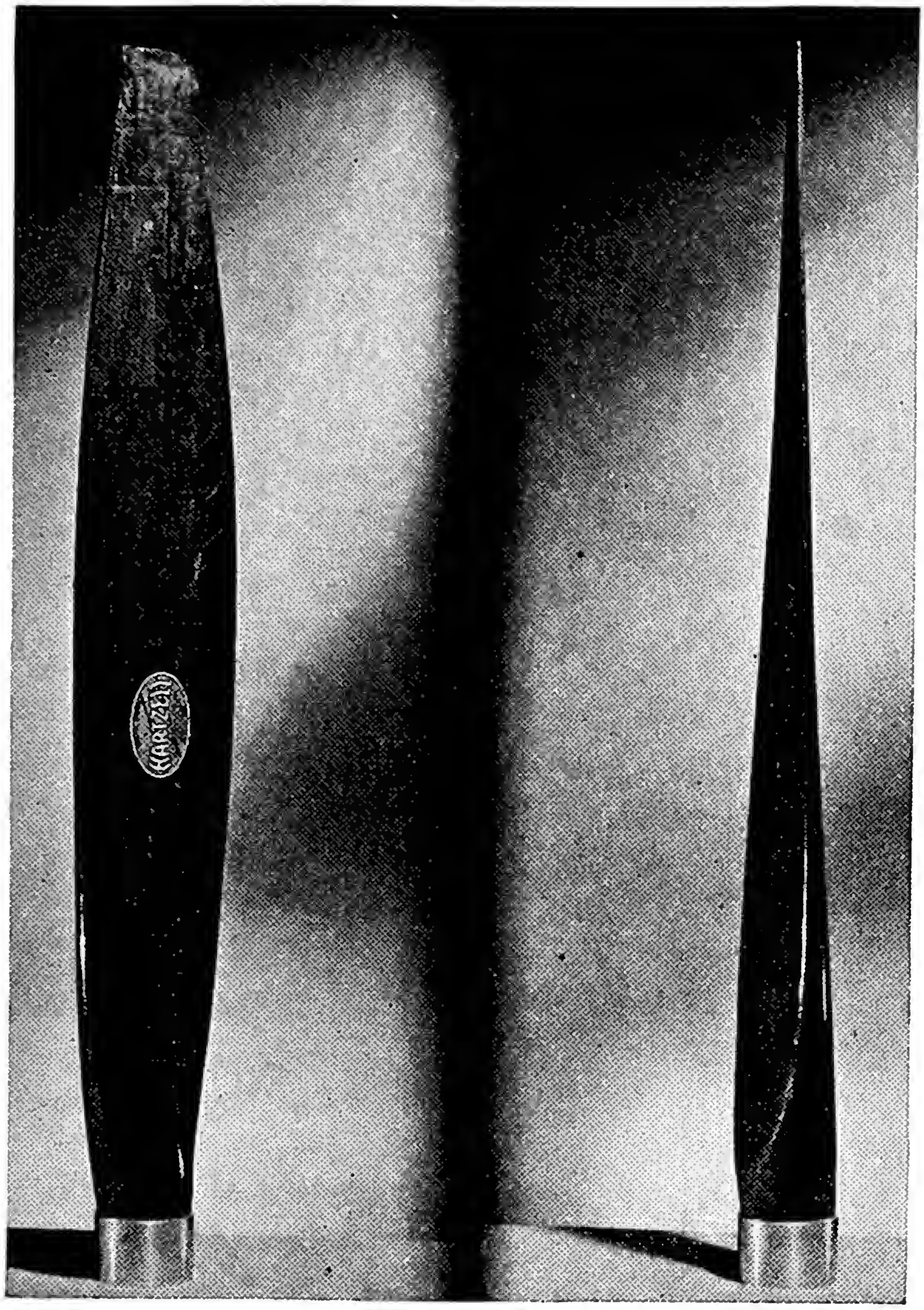
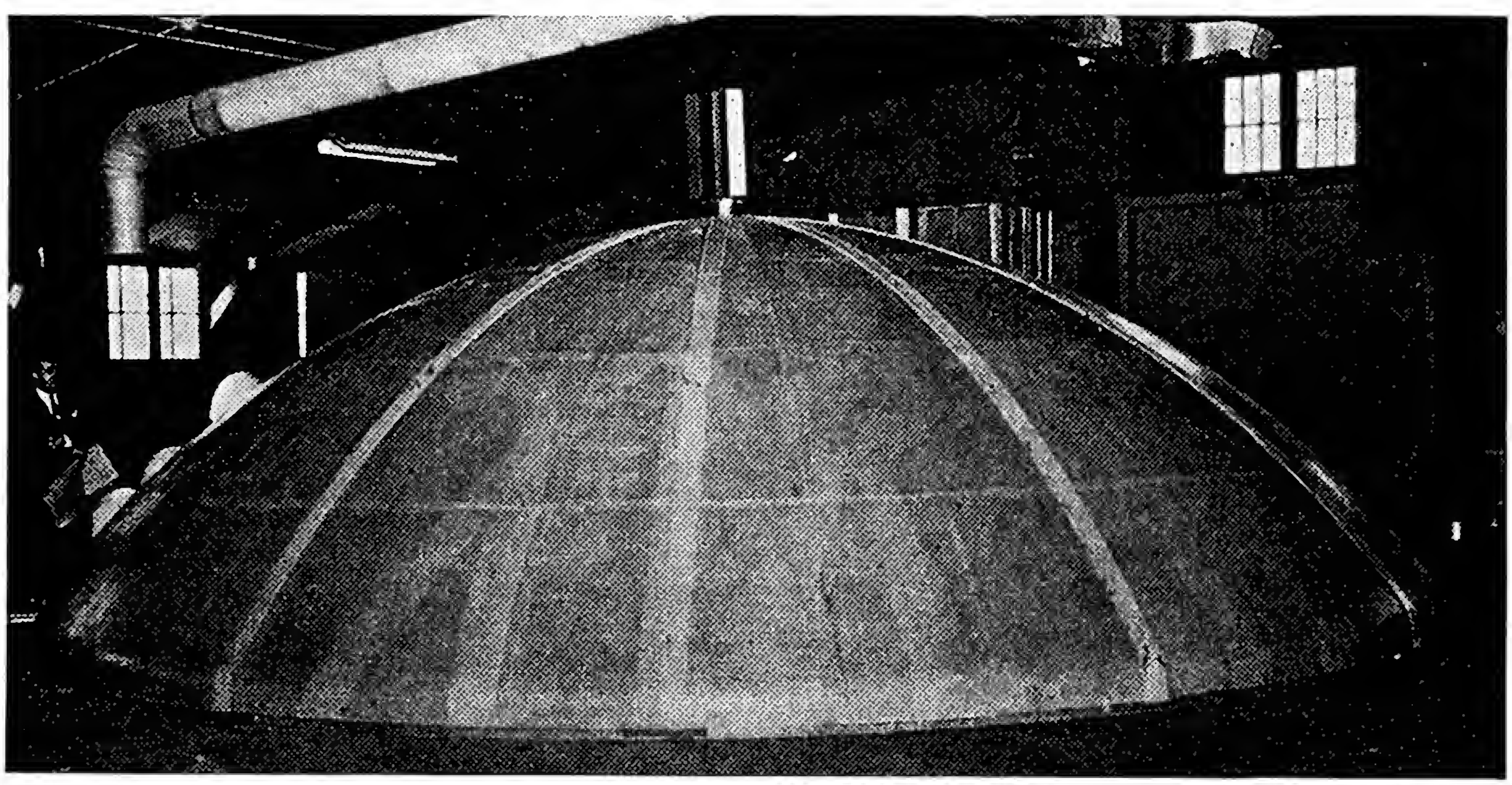


FIGURE 34.
Fiberglas reinforced plastic propeller blade.

Courtesy Hartzell Industries, Piqua, Ohio



Courtesy U. S. Plywood Corp., New York, N. Y.

FIGURE 35. A very large Radome made in twelve sections of Fiberglas skins—low pressure molding.

Cloths Available: X-2127,* (0.005″) (Four-Harness)

181-14 (0.0085″)
182-14 (0.013″)
183-14 (0.018″)
184-14 (0.027″)

	181-14	*182-14*	*183-14*	*184-14*
Nominal thickness	0.0085″	0.013″	0.018″	0.027″
Weight (oz. per sq. yd)	8.90	12.40	16.75	25.90
Approx. break strength (lbs.)				
Warp	340	440	650	950
Fill	330	400	620	800
Standard width	38″	38″	38″	38″

Knitted Fabrics

General properties of the laminate:

Same as for Unidirectional cloths, described on page 64.

Recommended uses:

(1) Where smooth lapless surfaces are required.

(2) Where the Fiberglas inherent properties are required along with the simplicity of forming.

Fabrics available: X-10097*

Type X-10097, Continuous filament	
Nominal thickness	21 mils (Single)
Weight (oz. per sq. yd.)	9.69
Approx. bursting strength (lbs. per sq. in.)	169
Standard width	34″ (Flat Tubular) 68″ (Single Flat)

Fiberglas Mats†

General properties of the laminates:

Medium tensile, compressive, flexural, impact and modulus
High temperature resistance
Dimensional stability
Low specific gravity
Corrosion resistance
Low thermal expansion

* These X numbers are experimental numbers and are subject to change when standardized.

† The nomenclature of mats may be changed in the future. New names will be cross-referenced to the older names.

Recommended uses:

(1) Where an unusually well balanced reinforcing material is needed, at a lower price than cloth.

(2) Where low loss electrical properties are required.

(3) As a core material to be used with the thin satin cloths as skins.

Type	*T34-A*	*T34-K*	*T35- K*
Binder	Vinyl	Phenolic	Thermosetting resin fully cured
Thickness (average)*	50 mils	50 mils	25 mils
Weight (oz. per sq. ft.)	1.5 on 0.050″ mat	1.5	2.08 on 0.025″ mat
Tensile strength (lbs. on per inch strip)	5	3	10
Standard width†	38″	38″	36″

* Available in 20, 50, 75 and 100 mils.
† Available in increments of 2″ from 36″ to 60″.

Starch Fiberglas Mat

Binder	Starch	Phenolic	Furfuryl
Thickness (mils)	20	40	20
Weight (lb. per sq. ft.)	0.0153	0.028	0.0142
Tensile strength (lb. per in. strip)			
Lengthwise	12.0	18.7	14.5
Crosswise	4.6	16.9	9.6
Standard width	22″ & 36″	same	same

Milled Fibers (¼″)

General molded or laminated properties:

Medium tensile, compressive, flexural, impact and modulus.

Improved temperature resistance, dimensional stability, and impact strength.

Recommended uses:

(1) Where added physical properties are required in a resin, that is either molded or laminated.

(2) Where added impact strength is required in a resin that is either molded or laminated.

(3) Where added light diffusion properties are desired in a resin that is either molded or laminated.

Milled fibers available:

Screen sizes: $\frac{1}{32}$″, $\frac{1}{16}$″, $\frac{1}{8}$″, $\frac{1}{2}$″, $\frac{3}{4}$″, 1″, $1\frac{1}{2}$″ (Special sizes subject to approval of Owens-Corning Fiberglas may be manufactured.)

Type No. 22: General Molded properties of Fiberglas basic fibers:

Medium high tensile, compressive, flexure, impact and modulus.
High temperature resistance
Dimensional stability
Low specific gravity
Low thermal expansion

Recommended uses:

(1) Where a product that can be pulp- or air-preformed to make parts of a complicated nature.

(2) Where the molded part requires the inherent properties imparted by Fiberglas.

References

"Plastic Molds for Electronic Vulcanizing," *Modern Plastics*, 23, No. 11, pp. 142-145 (July, 1946). For the successful electronic vulcanization of rubber products, which cuts cure time and improves quality, molds must be dielectric—a property possessed by resin-impregnated Fiberglas fabric molds.

"Data on Low Pressure Laminating Resins," *Modern Plastics*, 23, No. 10, pp. 144, 145 (June, 1946); 23, No. 11, p. 146 (July, 1946). Data and chart covering properties and handling of resins commonly used in combination with Fiberglas reinforcements; end applications are listed.

"Molding Laminated Foot Appliances, *Modern Plastics*, 23, No. 10, pp. 114-116 (June, 1946). Properties of Fiberglas-reinforced plastic laminate which led to its selection as material for molding prosthetic foot appliances, fitted to individual requirements, description of molding technique.

"Precision Labeling with Reinforced Plastics," by Prescott Fuller, *Modern Plastics* 23, No. 9, pp. 98, 99 (May, 1946). In a labeling machine the parts that hold the article in position while the label is being attached must be to exact tolerances. To achieve this precision, holders are produced from Fiberglas-plastic molds.

"Production of Honeycomb Cores," by J. D. Lincoln, *Modern Plastics*, 23, No. 9, pp. 127-129 (May, 1946). Description of process employed in production of resin-impregnated Fiberglas cloth honeycomb structures used as cores of high-strength structural panels.

"Reinforcement for Plastic Laminates," in *Chem. Eng. News*, 24, No. 5, p. 684 (Mar. 10, 1946). Properties and methods of using new Fiberglas mat material for plastics reinforcement.

"Properties and Fabrication of Glass Reinforced Plastics," *Materials and Methods*, 23, No. 3, pp. 720-724 (Mar., 1946). Properties of Fiberglas-reinforced plastic materials indicate their use for many types of products where strength and stability are required.

"Plastics Reinforcement," *Product Engineering*, 17, No. 3, pp. 258, 259 (Mar., 1946). Properties and methods of using newly developed Fiberglas knitted cloth as plastics reinforcement.

"New Fiberglas Knitted Cloth for Plastics Reinforcement," *Industrial Bulletin*, **4**, No. 6, pp. 2, 3 (Feb. 25, 1946). In laminates having complex curvatures, an unbroken surface with an attractive texture can be obtained by using stretchable Fiberglas knitted cloth to cover Fiberglas reinforcements that must be tailored to conform to the curvatures.

"Melamine Glass-Cloth Laminates Properties and Machinability," by P. C. Fuller, *Product Engineering*, **17**, pp. 142-145 (Feb., 1946). The physical and electrical properties of glass-fabric melamine-formaldehyde laminates are described. These materials are outstanding in their arc and heat resistance. They are being used by the Navy on ships as coil spacers, pole collars, mounting boards, panels, terminal plates, blocks for generators and motors, brush holders, washers, connector strips and brush tube caps. Detailed information on sawing, drilling, tapping, turning, sanding, milling, shearing and punching these plastic materials is given.

"Doron Armor . . . An Achievement and a Promise in Plastics," *Chem. Met. Eng.*, **53**, No. 2, pp. 154-157 (Feb., 1946). By laminating Fiberglas cloth with a contact resin there was produced during the war a light armor known as "Doron" that surpassed any metallic armor in ballistic efficiency.

"Resin-Bonded Glass Fiber Fly-Rod," by Arthur M. Howland, *Modern Plastics*, **23**, No. 6, pp. 124-125 (Feb., 1946). Fly-rod surfaced with resin-bonded glass fibers, over wood core, is stronger and lighter than traditional bamboo rod.

"Many Railroad and Other Uses Foreseen for New Glass-Plastic Material with Metal-Like Properties," *Railroad Equipment*, **1**, No. 5, p. 8 (Jan.-Feb., 1946). Combination of Fiberglas reinforcement and lowpressure resins make it possible to mold large, lightweight, high-strength parts without use of costly dies.

"The Automotive Industry . . . What It Needs from the Plastics Industry," by William B. Stout, *Modern Plastics*, **23**, No. 5, pp. 107-109 (Jan., 1946). The article states: "So far, the most promising material for laminates for car structures has been created bv the glass industry. Glass fibers have been worked into laminates that have structural strengths that are even greater than those of the highest grade steels."

"Knitted Fiberglas Cloth," *Pacific Plastics*, **4**, No. 1, p. 45 (Jan., 1946). Knitted Fiberglas cloth that can be stretched to conform to complex curvatures produced for use as plastics reinforcement.

"Advances in Plastics During 1945," *Modern Plastics*, **23**, No. 5, pp. 161-164, 196, 198, 200, 202, 204, 206 (Jan., 1946). Summary of technical progress during 1945, including numerous references to Fiberglas-plastic combinations. Bibliography of significant articles published during 1945.

"A Year in Plastic Engineering," *Modern Plastics*, **23**, No. 5, pp. 125-135, 190 (Jan., 1946). Summary of engineering developments during 1945, including numerous references to Fiberglas-plastic combinations.

"Glass Laminates and Their Application to Aircraft Structures," by G. B. Rheinfrank, Jr., and W. A. Norman, *Aeronautical Eng. Rev.*, **5**, No. 1, pp. 10-14, 82 (Jan., 1946). Fiberglas-plastic laminates provide light-weight, high-strength material for aircraft structures.

"Melamine-Bonded Fiberglas Laminates," by Gerard A. Albert, *Plastics*, **3**,

No. 6, pp. 82, 105-108 (Dec., 1945)..Need for shatterproof, arc-resistant electrical panel board is met by a melamine-bonded Fiberglas-base laminate, one of the distinctive developments in plastics to come out of the war.

"It's in the Bag," *Petroleum Engineer*, 17, No. 2, pp. 240, 242 (Nov., 1945). Use of Fiberglas-plastic combinations makes possible production of high-strength parts without employing costly dies.

"Armored in Glass," by Robert Devore, *Colliers*, **116**, No. 14, pp. 92-94 (Oct. 6, 1945). Fiberglas cloth, impregnated and bonded with a resin, used as body armor material in life jackets worn by sailors in landing craft, P-T boats, rocket ships and other amphibious operations vessels.

"Fabric Laminates—Growing Outlet for Textiles," by Harold E. Reed, *Textile World*, **95**, No. 10, pp. 107-109 (Oct., 1945). Construction of Fiberglas fabrics employed as reinforcement for plastics.

"Machining Fiberglas Plastics," by Harry Crump, *Machine Tool Blue Book*, **41**, No. 10, pp. 211, 214, 216, 218, 220, 222, 224 (Oct., 1945). Techniques employed in machining Fiberglas-reinforced plastics.

"Structural Materials Made from Fiberglas Fabrics," by John Reeves, *Textile World*, **95**, No. 10, pp. 110-112 (Oct., 1945). Combinations of Fiberglas-reinforced plastic faces with a light-weight cellular core having possibilities in production of truck and trailer bodies, airplanes, boats and portable houses.

"Glass Armor Protected American Seamen," *Science News Letter*, **48**, No. 9, p. 136 (Sept. 1, 1945). Thin Fiberglas-plastic plates, placed in pockets of life vests or other garments, protected sailors, and marines from flying shell splinters.

"Fiberglas-Plastic Binocular Carrying Case," *Purchasing*, **19**, No. 3, p. 246, (Sept., 1945). Fiberglas-plastic carrying cases for high precision optical instruments possess high impact and flexural strength; are unaffected by fungi attack.

"Fiberglas Cases . . . Protect Navy's Optical Instruments," *Marine Equipment*, **3**, No. 9, p. 8 (Sept., 1945). Fiberglas-plastic optical instrument cases withstand Navy service conditions that cause organic-material cases to deteriorate.

"It's in the Bag . . . New Technique Simplifies Low Pressure Laminating of Small Parts," *Modern Industrial Press*, **7**, No. 9, p. 52 (Sept., 1945). Costs are cut by molding parts out of Fiberglas-reinforced plastics instead of fabricating them out of metal.

"Plastic Armor," *Time*, **46**, No. 10, p. 56 (Sept. 3, 1945). Body armor made of thin sheets of Fiberglas cloth, impregnated and bonded with resin, saved lives of World War II marines, soldiers and sailors.

"Fiberglas-Plastic Cases Protect Precision Optical Instruments," *Marine Progress Weekly*, **13**, No. 33, p. 4 (Aug. 15, 1945). Laminated carrying cases, made of vinyl- and phenol-impregnated Fiberglas fabric, provide Navy optical instruments with maximum protection under all service conditions in all climates.

"Development of Molded Fiberglas for Primary Aircraft Structures," by Captain George B. Rheinfrank, Jr., and Captain Wayne A. Norman, AAF, ATSC, *Aero Digest*, **50**, No. 3, pp. 72-75, 139 (Aug. 1, 1945). Detailed description of

materials and fabricating techniques employed in molding Fiberglas-plastic fuselage for Army BT-15 plane.

"Air Ducts on the B-29," *Modern Plastics*, **22**, No. 12, pp. 136-140 (Aug., 1945). Description of the fabrication of Fiberglas-reinforced plastic air ducts which replaced metal ducts on the B-29's.

"Tips on Machining Fiberglas Plastics with Carbide Tips," *Tool and Die Journal*, **11**, No. 5, pp. 110-111 (Aug., 1945). Pictorial presentation of techniques employed in machining Fiberglas-reinforced plastics with carbide-tipped tools.

"Windowless American Airlines Air-freighter Another Boost for Air Cargo Transportation," *Air Transportation*, **7**, No. 2, p. 24 (Aug., 1945). Interior of American Airlines "flying boxcar" is lined with Fiberglas cloth impregnated and bonded with resin to form tough, durable sheathing.

"Plastic Tooling Procedures," by E. L. Maris, *Iron Age*, **156**, No. 3, pp. 55-61 (July 19, 1945). Techniques for handling thermo-setting casting resins and laminates having paper and fabric (including Fiberglas fabric) bases.

"AA 'Flying Boxcar' Put into Service on Flagship Fleet," *American Aviation*, **9**, No. 4, p. 55 (July 15, 1945). Tough, durable, Fiberglas plastic sheets used to line interior of American Airlines air freighter.

"A High-Strength Plastic Laminate," *Iron Age*, **156**, No. 2, pp. 62, 63 (July 12, 1945). Use of high-strength, Fiberglas-plastic laminate for intricate aircraft parts saves time, tools and labor.

"Plastic Tooling," *Plastics World*, **3**, No. 7, pp. 18, 19 (July, 1945). Laminated tools made of Fiberglas fabric impregnated with a contact-pressure resin are being increasingly employed by industry because of their light-weight, rigidity, high impact strength and ease of fabrication.

"Machining Fiberglas-Reinforced Plastics," by Frank E. Allen, *Industrial Plastics*, **1**, No. 2, pp. 10-15 (July, 1945). Techniques and tools employed in machining Fiberglas-reinforced plastics.

"Molding by Low Pressure," by W. Burdette Wilkins, *Plastics*, **3**, No. 1, pp. 102-104, 106, 146-148 (July, 1945). In molding plastic radar housing, the ultimate weight-strength factor was achieved by use of Fiberglas cloth as the reinforcement for the plastic.

"Flame-Resistant Laminate for Navy," by Louis C. Chesley and Prescott C. Fuller, *Modern Plastics*, **22**, No. 10, pp. 136-140, 190 (June, 1945). The development, fabrication and properties of Fiberglas-melamine laminate adopted for panel boards on U. S. Navy ships.

"New Glass-Fibre Laminate," *Electrical Manufacturing*, **35**, No. 6, pp. 150, 152 (June, 1945). New laminate made of thin, porous Fiberglas mats impregnated and bonded with a resin, greatly extends the field for plastic coil forms, condenser spacers, stand-off insulators, etc. in radio, television and other high-frequency electronic devices.

"Pyrolizer Solves Bonding Problem," by D. J. O'Conor, Jr., *Modern Plastics*, **22**, No. 9, pp. 138, 139 (May, 1945). Description of device developed by plastics

fabricator for heat-treating Fiberglas cloth to secure maximum bond between cloth and resin in building up a laminate.

"New Plastic Laminate for Aircraft Parts," by Thomas A. Dickinson, *Southern Flight*, 23, No. 5, pp. 36, 37 (May, 1945). Resin-impregnated fabrics, including Fiberglas, are replacing metal in numerous components of planes.

"All-Laminate Construction Bids for Aircraft Uses," by Leonard S. Meyer and John C. Case, *Aviation*, **44**, No. 5, pp. 141-144 (May, 1945). Informative details on the experimental production of a complete fuselage section of all-laminate sandwich construction, including core material. Composed of resin and Fiberglas cloth, this material offers interesting possibilities for mass fabrication of aircraft components.

"Some Recent Developments in Engineering Materials," by Archibald Black, *Mech. Eng.*, **67**, No. 4, pp. 267-273 (April, 1945); **67**, No. 5, pp. 334-343 (May, 1945). Engineering properties of glass fibers which have led to their use as reinforcement for plastics; other uses, and processes employed in manufacturing glass in fiber form.

"Application of Plastic Materials in Aircraft," *Automotive and Aviation Industries*, **92**, No. 8, (pp. 38, 112, 114, 116, 118 (April 15, 1945). Applications of Fiberglas-reinforced plastics to aircraft construction; materials used for cabin structure of R-6 helicopter.

"Glass Fiber Plastics Make Good Air Ducts," *Pacific Plastics*, **3**, No. 4, p. 23 (April, 1945). Tooling costs and production time cut by use of Fiberglas-reinforced plastics for aircraft air ducts; fabricating techniques.

"Shells Pierce Glass Plane Without Exploding," *Popular Mechanics*, **83**, No. 4, p. 75 (April, 1945). Air Technical Service Command reports that Fiberglas-reinforced plastic plane fuselage does not "flower" when struck by shells, and that because of the low density of the material high explosive shells do not detonate.

"Machining Glass-Reinforced Plastic with Cemented Carbide Tools," by Harry Crump, *American Machinist*, **89**, No. 7, pp. 91-93 (Mar. 29, 1945). Techniques employed in drilling, turning, milling, punching, tapping and blanking Fiberglas-reinforced plastics.

"Glass-Fabric Jig Devised for Drilling Contoured Surfaces," *American Machinist*, **89**, No. 1, p. 87 (Jan. 4, 1945). Description of the fabrication of a Fiberglas-reinforced plastic jig used for accurately locating and drilling 86 holes in an aircraft wing assembly.

"Protection for Fuel Cells," *Aviation*, **44**, No. 1, p. 177 (Jan., 1945). Drawing showing installation of sheet of resin-impregnated Fiberglas cloth as protective lining in Superfortress fuel cell cavities.

"Glass-Laminated Sheets Safeguarded Superfortress Tanks," *Product Engineering*, **16**, No. 1, p. 37 (Jan., 1945). Photograph showing installation of sheet of resin-impregnated Fiberglas cloth as protective lining in Superfortress fuel cell cavities.

"Plastic Products," *Modern Plastics*, **22**, No. 5, p. 120 (Jan., 1945). Description of the fabrication of a Fiberglas-reinforced plastic jig used for accurately locating and drilling 86 holes in an aircraft wing assembly.

"Glass Plastic . . . A New Material," by William H. Page, "Book of Knowledge" 1945 Annual, pp. 149, 150. Properties, fabrication and uses of Fiberglas-reinforced plastics.

"Resin-Bonded Glass Fiber Fly-Rod," by A. M. Howald, *Modern Plastics*, **23**, No. 6, p. 124 (1946). Details of construction of a fly-rod surfaced with resin bonded glass fibers. The rod is 8 ft. long and weighs 3½ ozs.

"Weave as it Affects Glass Cloth Laminates," by Fred J. Meyer and Erven White, *Modern Plastics*, **23**, No. 3, p. 137 (1945). In glass fabric laminates, the highest strengths are to be obtained from the thinnest cloths. This conclusion is based on a series of tests carried out on plain-woven glass fabrics.

"Reinforced Plastics for Aircraft Construction," *Engineering* (London, England), February 9, 1945. Successful use of Fiberglas-reinforced plastics for load bearing parts of aircraft.

"Helicopter Cabins Will Incorporate New Plastics Structural Material," *Scientific American*, **172**, No. 1, p. 48 (Jan., 1945). Cabin structures of new R-6 military helicopter are built of molded Fiberglas reinforced plastic laminate.

"Glass Plastic Aeroplane Fuselage," *Machinery Lloyd* (London, England), November 15, 1944. Successful use of Fiberglas-reinforced plastics for construction of load-bearing parts of aircraft.

"Fiberglas-Resin Sheets," *New Equipment Digest*, **9**, No. 12, p. 1 (Dec., 1944). Fiberglas-resin sheets used as lining in cargo spaces of Pennsylvania Central Airlines transport planes to guard metal fuselage skin from contact with heavy items of cargo.

"Glass for Strength," by David O. Woodbury, *Colliers*, **114**, No. 15, p. 64 (Oct. 7, 1944). Significance of high strength properties imparted to plastics by glass fibers used as reinforcing material.

"Special Lining for Cargo Compartments," *Air Transport*, **2**, No. 12, p. 119 (Dec., 1944). Fiberglas-resin sheets used as lining in cargo spaces of Pennsylvania Central Airlines transport planes to guard metal fuselage skin from contact with heavy items of cargo.

"The Hub of the Home," by J. D. Lincoln, *Modern Plastics*, **22**, No 2, pp. 118-121, 194 (Oct., 1944). Properties of Fiberglas-reinforced plastics indicated their use in construction of prefabricated kitchen and bathroom units.

"Combinations of Plastics and Glass Fibres," by Frank W. Preston, *British Plastics* (London, England), **16**, No. 185, pp. 440-445 (Oct., 1944). Evaluation of new engineering data on Fiberglas-reinforced, low-pressure plastic laminates.

"Increasing the Compressive Strength of Fiberglas-Reinforced Plastics," by Games Slayter, *Engineering Experimental Station News*, published by the Engineering Experiment Station, Ohio State University, **16**, No. 4, pp. 3-8 (Oct., 1944). Development of fabricating processes which increase compressive strength of Fiberglas-reinforced plastics.

"Plastics for Aircraft," *Modern Transport* (London, England), **51**, No. 1330, p. 7 (Sept. 9, 1944). Successful use of Fiberglas-reinforced plastics for construction of load-bearing parts of aircraft.

"Strength of New Plastics Compares with that of Metal," by John Delmonte, *Machine Design*, **16**, No. 8, pp. 119-122 (Aug. 8, 1944). Techniques employed in

fabricating high-strength resin-bonded Fiberglas laminates. Properties of the laminates.

"Plastic Plane," *Liberty*, 21, No. 28, p. 12 (July 8, 1944). Successful use of Fiberglas-reinforced plastics for construction of load-bearing parts of aircraft.

"Glass-Reinforced Plastics, *Scientific American*, **171**, No. 1, p. 28 (July, 1944). Successful use of Fiberglas-reinforced plastics for construction of load-bearing parts of aircraft.

"Glass Laminates and Textiles Beckon Product Planners," *Modern Industry*, 7, No. 6, pp. 47, 132 (June 15, 1944). Fiberglas textiles and low-pressure laminates reinforced with Fiberglas point to new product developments.

"Training Plane Built of Laminated Glass-Reinforced Plastics with Balsa Core," in *Product Engineering*, **15**, No. 6, p. 420 (June, 1944). Successful use of Fiberglas-reinforced plastics for construction of load-bearing parts of aircraft.

"Glass-Reinforced Plastics for Aircraft Construction," *Aeronautical Engineering Review*, 3, No. 6, pp. 195, 197 (June, 1944). Successful use of Fiberglas-reinforced plastics for construction of load-bearing parts of aircraft.

"New Glass-Plastic Airplane Material Announced," *Ceramic Industry*, **42**, No. 6, p. 32 (June, 1944). Balsa wood core between an inner and outer skin of plastic reinforced with fibrous glass cloth 50 per cent stronger than metal and 80 per cent stronger than wooden fuselages now in service.

"Significance of New Data on Combinations of Plastic and Glass Fibers," by Frank W. Preston, *Glass Industry*, **25**, No. 6, pp. 266-267, 284, 287 (June, 1944). Evaluation of new engineering data on Fiberglas-reinforced low-pressure plastic laminates.

"AAF Tests Plastic Plane at Dayton," *American Aviation*, 7, No. 24, p. 68 (May 15, 1944). Tests of Army basic training plane show successful use of Fiberglas-reinforced plastic for construction of fuselage, side panels and tail cone.

"Army Experimental Plane Has Glass-Reinforced Plastic Fuselage," *Automotive and Aviation Industries*, **90**, No. 10, pp. 29, 212 (May 15, 1944). Successful use of Fiberglas-reinforced plastics for construction of load-bearing parts of aircraft.

"Laminated Glass Tested for Aircraft Structural Members," *Iron Age*, **153**, No. 19, p. 146 (May 11, 1944). Tests of Army basic training plane show successful use of Fiberglas-reinforced plastic for construction of fuselage, side panels and tail cone.

"Plastic Fuselage Glass-Reinforced," *Iron Age*, **153**, No. 18, p. 101 (May 4, 1944). Photographs of aircraft parts made of laminated Fiberglas.

"Structural Materials," *Chem. Met. Eng.*, **51**, No. 5, p. 149 (May, 1944). Successful use of Fiberglas-reinforced plastics for construction of load-bearing parts of aircraft.

"Glass-Reinforced Laminates for Structural Plane Parts," *Tool and Die Journal*, **10**, No. 2, pp. 98L, 98M, 98P (May, 1944). Successful use of Fiberglas-reinforced plastics for construction of load-bearing parts of aircraft.

"Fabrication of Experimental Low-Pressure Laminates," *Modern Industry*, **21**, No. 9, pp. 104-106 (May, 1944). Methods and materials employed in fabricating test specimens of Fiberglas-reinforced low-pressure plastic laminates.

"The Versatility of Low-Pressure Molding," by David Swedlow, *Modern*

Plastics, **21**, No. 9, pp. 112, 184 (May, 1944). Some considerations affecting fabrication of Fiberglass-reinforced low-pressure laminates in the form of flat sheets and shaped parts.

"Desirable Handling Properties of Low-Pressure Resins," by J. D. Lincoln, *Modern Plastics,* **21**, No. 9, pp. 110-111 (May, 1944). Desirable handling properties of resins employed in fabricating Fiberglas-reinforced low-pressure plastic laminates.

"Machining Glass-Reinforced Low-Pressure Laminates," by Frank E. Allen, *Modern Plastics,* **21**, No. 9, pp. 107-109 (May, 1944). Methods employed in drilling, punching, sawing, grinding, turning, tapping, threading, milling, shaping and shearing Fiberglas-reinforced low-pressure plastic laminates.

"Forms, Properties and Handling of Glass Reinforcements," *Modern Plastics,* **21**, No. 9, pp. 100-103 (May, 1944). Properties and methods of handling Fiberglas fibers and fabrics employed to reinforce plastics.

"Application of Glass Laminates to Aircraft," by Captain George B. Rheinfrank, Jr., and Lieutenant Wayne A. Norman, *Modern Plastics,* **21**, No. 9, pp. 94-99 (May, 1944). Methods employed in constructing Fiberglas-reinforced plastic fuselage, side panels and tail cone for a BT-15 (Army Basic Training) plane; results of strength tests of fuselage.

"Development of Glass-Reinforced Low-Pressure Plastics for Aircraft," by Colonel Paul H. Kemmer, *Modern Plastics,* **21**, No. 9, pp. 89-93 (May, 1944). Account of the development of Fiberglas reinforced low-pressure plastics for use in construction of load-bearing parts of aircraft; properties of the material.

"Molded Laminates," *Modern Industry,* **7**, No. 4, pp. 34-39 (April 16, 1944). Development and applications of high-strength plastic laminates; uses of Fiberglas as reinforcement.

"Glass Cloth Plus Resin for Plane Building," *Manufacturers Record,* **113**, No. 1, pp. 44, 45 (Jan., 1944). Glass fibers employed as reinforcements for plastics to produce new light-weight, high-strength material for aircraft construction.

"The Role of Minerals in Our Future Economy," by Games Slayter, *Mining and Metallurgy,* **24**, No. 444, pp. 546-550 (Dec., 1943). Address delivered before the Industrial Minerals Division, American Institute of Mining and Metallurgical Engineers (Oct. 22, 1943) at Wilmington, Delaware, containing remarks on the use of glass fibers as reinforcement for plastics.

"Plastic Material Reinforced by Glass Fibers, *Aeronautical Eng. Rev.,* **2**, No. 12, p. 175 (Dec., 1943). Glass fibers employed as reinforcement for plastics to produce new light-weight, high-strength material for aircraft construction.

"Fiberized Plastic," *Modern Industry,* **6**, No. 5, pp. 18, 20 (Nov. 15, 1943). Glass fibers employed as reinforcement for plastics to produce new light-weight, high-strength material for aircraft construction.

"Glass Fibers Reinforce Plastics Used in Aircraft," *Science News Letter,* **44**, No. 19, p. 296 (Nov. 6, 1943). Glass fibers employed as reinforcement for plastics to produce new light-weight, high-strength material for aircraft construction.

"Glass-Plastic Material," *Chem. Ind.,* **53**, No. 5, p. 714 (Nov., 1943). Glass

fibers employed as reinforcement for plastics to produce new light-weight, high-strength material for aircraft construction.

"Fiberglas-Reinforced Plastics," by Tyler Stewart Rogers, *Modern Plastics*, 21, No. 1, pp. 88, 140, 142 (Sept., 1943). Use of glass fibers as reinforcement for plastics.

Another glass material called "Satinglas" is available as a reinforcing material for plastics. It is manufactured by:

Glassfloss Corp., 115 East 44th Street, New York 17, N. Y.

Descriptive literature states that this glass is available in rolls 48″ wide and 19 yds. long; and in sheets 36″ x 48″. This material is made from continuous monofilament glass fibers. The binding agent employed depends upon the intended application, so that the product will be compatible with such resins or other materials as used in the processing. Glass floss is supplied in a wide range of colors for decorative purposes such as wall covering, table tops and sink tops. Other uses are for electrical insulation, for structural assemblies and for chemical and air filtration media.

Paper

Paper-base laminated plastics have long been used in the electrical field. Special grades of paper free from sizing and metallic particles are used. The proper rate of absorption for the resins is necessary. Low cost is an outstanding advantage of paper as a reinforcing material.

Average physical strength values for paper laminated phenolics are:

Tensile strength		7,000-12,500 psi
Flexural strength		15,000-21,000 psi
Compressive strength	(flatwise)	22,000-35,000 psi
	(edgewise)	12,000-18,000 psi

Rag paper is used primarily for tubing and electrical applications. The Mitscherlich special sulphite paper is the so-called "high-strength" paper. Other types of papers used are: kraft, Mitscherlich sulphate paper and alpha-cellulose. Since ordinary papers have little formability, new varieties of both one-way and two-way creped papers have been developed. Use of these products in laminates permits deeper draws, and eliminates the need for preforming.

Mr. J. D. Line, Technical Director of the Mosinee Paper Mills Company, Mosinee, Wisconsin, supplies the following information on the range of characteristics of a number of laminating papers:

Basis weight (24 x 36 x 500) from 21 to 146#.
Thickness from 0.002 to 0.020.
Apparent density (g/cc) from 0.43 to 0.68.
Gurley densometer seconds per 100 cc from 4 to 30.
Klem strip (5 minutes) from 4/16" to 28/16".
A.S.T.M. oil penetration in seconds per mil. from 4 to 18.
Tensile strength in pounds per in. (% of weight) from 58 to 100 M.D.
Tensile strength in pounds per in. (% of weight)from 28 to 42 C. D.
Tensile strength P.S.I. from 4000 to 9400 M.D.
Tensile strength P.S.I. from 2000 to 4000 C.D.
Tear in grams per pound from 1.2 to 2.8 M.D.
Tear in grams per pound from 1.8 to 3.2 C.D.
Dielectric strength, volts per mil, from 100 to 230.
Percent ash content from .45 to 1.0.
Machine white water pH on regular pulp papers 7.5 to 8.2.
Machine white water pH on special washed pulp papers 6.8 to 7.2.

Fluid or hydraulic pressure is applied in low-pressure laminating in contrast to unidirectional or platen pressure usually employed in high-pressure techniques.

Paper-base reinforced laminates are used for such purposes as:

Cassette tops
Coil supports
Communication
Equipment panels
Gears and pinions
Radio parts
Refrigerator door trim
Relay bases
Switchboard panels
Tap changer bases
Terminal strips
Transformer terminal boards
Worktable tops

Some suppliers of paper for low-pressure laminating of plastics are:

Mosinee Paper Mills Co., Mosinee, Wisconsin.
Munising Paper Co., Munising, Mich.
Riegel Paper Corp., 342 Madison Ave., New York, N. Y.
Sorg Paper Co., Middletown, Ohio.

Rope

One of the best known materials in this field is "Co-Ro-Lite" as manufactured and sold by the

Columbian Rope Co., Auburn, New York.

This product is described as a "ready-to-mold, high-impact," industrial plastic compound, reinforced by long, tough rope fibers that form an interlocking system of remarkable qualtities. "In the Co-Ro-Lite process, cordage fibers, long famous for their strength and toughness, are carded and worked into a fluffy batting. This is consolidated by a needling operation which drives tufts of the fibers through the mass. The resulting felt-like blanket resembles a very thick coarse fabric, ranging up to ¾ of an inch or more in thickness and having a bulk ratio as high as 1 to 10. This high ratio of one part fiber to ten parts void space makes the batt readily receptive to resin solutions and powders while the interlaced structure of the fibers binds the batt firmly, making it practical to handle, cut and pre-form in preparation for molding."

This process is patented.

References

United States Patent 2,249,888, "Moldable Plastic Composition," July 22, 1941.

United States Patent 2,372,433, "Moldable Plastics Composition and Method of Preparing Same," March 27, 1945.

This rope fiber may be impregnated with resin and molded at 100 to 3000 psi to yield a *high density* material with a specific gravity of 1.15 to 1.35.

In this book we are particularly interested in the low-pressure field of laminating reinforced plastics. When a molding pressure of 40 to 100 psi and molding temperature of 275 to 350° F are used, a *low density* laminate with a specific gravity of 0.7 to 1.2 results. Other characteristics of such a laminate are:

	Low Density
Compression ratio	3:1
Tensile strength (psi)	4,000 to 9,000
Flexural strength (psi)	12,000 to 17,000
Compressive strength (psi)	5,000 to 20,000
Impact strength (ft. lb. per in. of notch, ½ x ½ in. notched bar, Charpy test)	3 to 12
Flexural modulus of elasticity (psi)	400,000 to 700,000
Water absorption (24 hr. immersion) (%)	2 to 15

The manufacturers state that their product is readily "adaptable to high pressure, low pressure, fluid pressure, flash and transfer molding," and lends itself to the production of "compound curves, deep draws, angles, channels and large shells with a minimum of preparation, 'lay-up' and curing time."

Fluid Pressure Molding of Co-Ro-Lite. "One of the natural outgrowths of low-pressure molding has been the development of the so-called 'bag' or 'fluid pressure' mold by which all pressure is fluid and therefore omnidirectional. This permits the development of large shell shapes with compound curvatures and streamline surfaces, such as boat hulls and cabins, airplane fuselages, fuel tanks and the like. The method eliminates the need for expensive dies and ponderous presses and tremendous pressures which would be required to operate them. Instead, simple molds with vacuum lines are used. Preforms from a single sheet of Co-Ro-Lite are laid into the mold, and the open side is sealed by a rubber blanket or other flexible membrane.

"Exhaustion of the air through the vacuum line immediately puts approximately 14 lbs. pressure per sq. in. on the mold and this is increased to 80 lbs. or more by wheeling the mold into an autoclave and building up heat through steam pressure which accomplishes the dual purpose of forming the Co-Ro-Lite sheet to the precise shape of the mold, at the same time curing it to permanent hardness. Users of plywood will recognize instantly the enormous saving in time afforded by using the single-piece Co-Ro-Lite preform as against the multiple strips of plywood which must be laid up and stapled together in the mold. At the same time, densities and specific gravities comparable to plywood are readily obtained."

It has been pointed out that one advantage of Co-Ro-Lite in molding formed parts such as boxes is its property of variable compressibility. In a lay-up or between dies, it lends itself to the laminator's desire to create a thin section of high impact strength, and thick sections of high elastic moduli. This is done with the one material without additional labor costs of "beefing up" or adding small sections of reinforcing material.

The low resistance of Co-Ro-Lite to moisture is alleviated by good surface coatings such as vinyl resins. A break in this protective coating may lead to troublesome after-effects.

"One of the first mass-production applications of this method was carried out by the Allied Products Division of the Columbian Rope Company in turning out Co-Ro-Lite jettison gasoline tanks for Army and Navy fighter and bomber planes. These auxiliary gasoline tanks, which are used on the first leg of a mission and dropped if contact with the enemy is made, provide extra gasoline

capacity up to 180 gallons each. They are molded under 80 lbs. steam pressure in an autoclave in two halves or shells which are later riveted together providing a light, tough tank which is sufficiently strong to withstand the tremendous forces to which it is subjected when the plane carrying it pulls out of a dive.

"Coloring agents for Co-Ro-Lite consist of pigments and dyes. Co-Ro-Lite made with phenolics are colored in the darker shades and those made with ureas, melamines, and thermoplastics can be made in the pastel shades.

"The question of what color to use is most important to the designer. Co-Ro-Lite's unique make-up gives designers unlimited possibilities for color and design. The fiber filler can be dyed and another color used as the binder. Also the fiber can be air-brushed to produce unusual color designs before applying the resin."

Reference

"Reinforcing Low Pressure Moldings," by J. D. Lincoln, *Modern Plastics*, p. 138 (March, 1946).

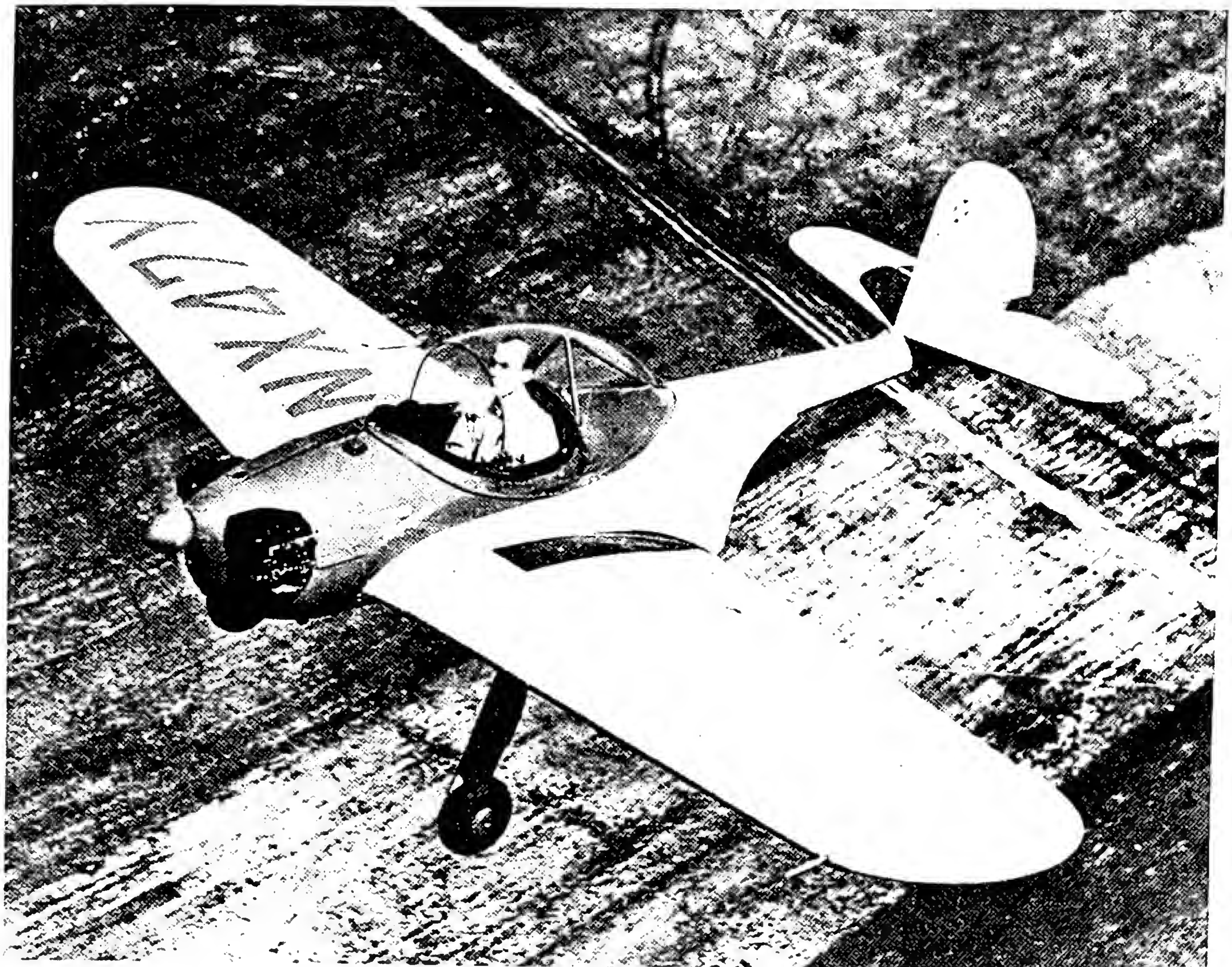
The use of such auxiliary reinforced plastic gasoline tanks as described in the preceding paragraphs was well known during World War II with numerous photographs of planes so equipped appearing in newspapers. A novel application of this reinforced plastic to the fuselage of a plane is shown in the experimental "Skycycle," built by

Piper Aircraft Corp., Lockhaven, Pa.

and shown to the public in New York City in 1945 (see Figure 36). Parts of the Co-Ro-Lite tank were used for the large section of the fuselage, as shown in Figure 36. In the future, designers envision the complete plane, fuselage and wings, to be molded in one piece by improved low pressure laminating techniques.

Sandwich Structures and Core Materials. Two sheets of laminated reinforced plastic may be cured with a "filler" or "core" material between them to produce a so-called "sandwich structure." The load per square foot which such a structure can sustain depends on the strength of the skins and also on the density (including crushing strength) of the core material.

A low-density core combined with a high-strength face layer gives the greatest strength to lightest weight ratio of various mate-



Courtesy Piper Aircraft Corp., Lock Haven, Pa.

FIGURE 36. A single place plane, the Piper Co. "Skycycle." Wing span, 20 ft.; cruises 105 mi. per hr.; weighs about 800 lbs.

rials. Good design makes it unnecessary to brace the structures except at points of load concentration.

Sandwich structures may consist of various combinations of the following materials:

Core Materials	*Surface Skin*
Balsa wood	Aluminum
Cellular cellulose acetate	Magnesium
Cork	Plywood
Hycar rubber	Reinforced plastic laminate
Plywood	Wood pulp fiber
Rubatex rubber	Other high strength materials
"Styrofoam"	
Other synthetics	

Applications for sandwich constructions include the following:

Airplane wings
Airplane fuselage
Boats
Lightweight wall panels
Lightweight flooring

Usually the core materials are of low density to give as great a strength with light weight as possible. Use of plywood only between skins is an exception, and is really intended for a different purpose.

The term "sandwich construction" has been applied to a combination of jute felt between glass mat as a laminate used for trailer fenders. It has also been applied to decorative panels composed of high strength paper skins over a core of heavy alpha cellulose paper. The design in color can be printed on one face skin and shows through the transparent laminating resin used.

Balsa wood is the lightest commercial wood in the world. It weighs 6 to 15 pounds per cubic foot, averaging under 10 pounds when dry. Balsa is lighter than cork and less brittle. The average specific gravity of balsa is 0.10. Improved methods of gluing, waterproofing, fireproofing and laminating will make it highly adaptable to uses in structural panels of great strength and rigidity at exceptionally low weight. Balsa wood may be obtained from:

Balsa Ecuador Lumber Corp., 500 Fifth Ave., New York 18, N. Y.

Mechanical Properties of Balsa (Data for pieces averaging 5% moisture content, and weighing from 5.18 to 14.36 pounds/cubic foot, oven dry).

*Compression Parallel to Grain**

(a) Elastic limit: 65 to 95% of ultimate strength.

(b) Modulus of elasticity: $Ec = 346{,}000\ (560\sigma - 1)$. (Ec in psi to the density, or in pci with mean limit variation of $\pm 92{,}000$ psi).

(c) Compressive strength parallel to grain: $Sc = 450\ (970\sigma - 1)$ with mean limit variation of ± 330 psi.

*Compression Perpendicular to Grain**

(a) Elastic limit: 43 to 127 psi with most values between 46 to 75 psi. Ec varied from 13,000 to 126,000 psi. Most values between 30,000 to 70,000 psi.

Beam Tests (free and supported and center loaded)*

(a) Modulus of rupture: $Sr = 1800\ (525\sigma - 1) \pm 650$ psi.

(b) Elastic limit: 76 to 94% of modulus of rupture.

(c) Modulus of elasticity in bending: $Eb = 229{,}000\ (625\sigma - 1) \pm 92{,}000$ psi.

*Column Tests**

(a) For slenderness ratios less than: 25, $P/A = 1400$ psi.

(b) For slenderness ratios of: 25 to 80, $P/A = 1800 - 17\ 1/r$ (where 1 is the unsupported length of the column and r is the radius of gyration of X section.

(c) For slenderness ratios greater than: 70 to 80, $P/A = \dfrac{1400}{1 + 0.00031\ (1r)^2}$

* *Proc. Am Soc. Testing Mat.*, 37 (II) pp. 582-7 (1937).

Strength of Balsa as Compared with Light Weight U. S. Species

	Wt. Per Cu. Ft. at 12% M.C.	Specif. Gravity	Modulus of Rupture (Bending Strength)	Modulus of Elasticity (Stiffness)	Compression Perpendicular to Grain Prop. Limit	Compression Parallel to Grain Ultimate	Cleavage
Balsa*	5	0.08	720	163,400	26	464	29
Balsa*	9	.144	2,160	456,000	49	1045	49
Balsa*	14	.244	4,176	800,000	78	1740	72
Northern White Pine†	25	.36	8,800	1,280,000	550	4840	160
Western Red Cedar†	23	.33	7,700	1,120,000	610	5020	130
Sitka Spruce	28	.40	10,200	1,570,000	710	5610	210
Basswood†	26	.37	8,700	1,460,000	450	4730	230
Buckeye†	25	.36	7,500	1,170,000	440	4170	240
Gumbo Limbo†	21	.31	4,800	740,000	560	3080	200
Balsam Poplar†	23	.33	6,800	1,100,000	370	4020	200
Northern White Cedar†	22	.31	6,500	800,000	380	3960	150

* Data on balsa interpolated from charts prepared by Draffin and Muhlenbruch; ASTM paper, 1937. Balsa test material was 5 per cent M.C. Since this M.C. gives higher values than the same wood at 12 per cent M.C., moisture-strength adjustment factors were applied. These were based on data contained in U. S. Forest Products Laboratory Technical Bulletin No. 479.

† Data from U. S. Forest Products Laboratory Technical Bulletin No. 479.

*Cleavage**

(a) Lbs./linear inch cleavage strength to density: $Scl=6\,(1430\sigma+1)$.

Thermal Conductivity(Btu/hr/sq ft/1 inch thickness/°F)

Across the grain
7.3 lb. per cubic foot 0.33 Btu
8.8 lb. per cubic foot 0.38 Btu

* *Proc. Am. Soc. Testing Mat.*, 37 (II) pp. 582-7 (1937).

Cellulose acetate in cellular form is called CCA by E. I. du Pont de Nemours & Co. It is available in densities ranging from 4 to 8 lbs. per cu. ft. It sells for approximately $0.25 to $0.56 a board foot, depending on the density. It may be machined with standard woodworking tools

The lower densities of CCA have the lower coefficients of thermal conductivity, K, which is approximately $0.3 + 0.05$ Btu-sq ft/hr/° F/in. Cold-setting resin adhesives of the phenol-formaldehyde or urea-formaldehyde type are recommended for cementing CCA to itself, to wood, or to skins of plastic. Curing pressures of 5 to 10 psi in bag molds have been found satisfactory. It is lighter than cork or balsa. Strips of the material 3½″ wide and ⅝″ thick are available. Applications are appropriate for airplane panels and floors, for luggage, for refrigerators and for many other articles.

References

"A Low-Density Structural Core," by R. E. Maier, *Modern Plastics*, p. 96 (May, 1946).

"Sandwich Structures with Foamed Core," by J. D. Lincoln, Jr., *Modern Plastics*, p. 132 (July, 1945).

"Core Materials for Sandwich Structures," by Capt. G. B. Rheinfrank, Jr., and Capt. W. A. Norman, *Modern Plastics*, p. 127 (July, 1945).

"It's the Skin," by N. J. Hoff, *Air Progress*, p. 13 (Sept., 1943).

"The Buckling of Sandwich-Type Panels," by N. J. Hoff and S. E. Mautner, *Aeronautical Sciences*, p. 285 (July, 1945).

"A Short History of the Development of Airplane Structures," by N. J. Hoff, *American Scientist*, Spring and Summer Issues, 1946.

"Production of Honeycomb Cores," by J. D. Lincoln, *Modern Plastics*, p. 127 (May, 1946).

"Foamglas" is a cellular glass material. Though it is not recommended as a structural load-bearing material, it will support evenly distributed loads of 5,000 lbs. per sq. ft. when properly protected from point loading.

Physical Properties of "Foamglas"

Specific gravity	0.17 (10 to 11 lbs. per cu. ft.)
K (Conductivity at 70°F.)	0.45 Btu/hr./sq. ft./°F/in.
K (Conductivity at 300° F)	0.70 Btu/hr./sq. ft./°F/in.
Coefficient of Expansion (°F)	0.0000046
Specific heat	0.16 to 0.19 Btu per lb. per °F
Crushing strength	150 psi
Modulus of rupture	90 psi
Impact strength (center drop-increment method, on 8" x 16" x 5" thick specimens supported on a 12" span)	66 ft.-lbs.
Absorption (24 Hr. immersion in water)	0.4% by volume, 2% by weight (All at surfaces)
Air infiltration or permeability	0
Capillarity	0
Volume change with moisture	0

This cellular form of glass is sold under the trademark of "Foamglas." It is produced by:

Pittsburgh Corning Corp., Grant Bldg., Pittsburgh, Pa.

Rubber is available in sponge form and cellular form for core materials.

"Hycar" core material is supplied by the Hycar Chemical Co., Akron, Ohio. "Rubatex" is an expanded type of insulation often used as a core material and supplied by Virginia Rubatex Division, Great American Industries, Inc., Bedford, Va.

Sandwich-type panels are often made today by preparing one skin or face of the panel, then tailoring the core material, such as blocks of cellular cellulose acetate, followed by curing the opposite skin or face to the core in the one operation of assembly.

An alternative method of construction consists of precuring both face panels, flat or contour in shape, then tailoring an expandible core material such as sponge rubber ("Celltite") in a pre-cure stage to fit approximately the space between panels. In the pre-cure stage the sponge rubber has undergone about four-fifths of its expansion, and in the final cure the rest of the expansion occurs. This assures good contact between the core and the skins. Foamed resins may be introduced between the skins to reduce the high cost of tailoring blocks of the material to fit. This development appears probable in the near future and should facilitate production line techniques for manufacturing sandwich panels.

Styrene has been prepared in a cellular form, called "Styrofoam," as made by the Dow Chemical Co., Midland, Mich. Its density is 1½ to 2 lbs. per cubic foot. It sells for $0.13 to $0.39 a board foot. Its compressive strength is 5 to 20 psi. It is lighter in weight than cork and after one week of submersion in water, it has about 30 per cent more buoyancy than cork. This material also has unusual electrical and thermal properties and excellent moisture resistance, which should lead to its greater use in the fields of aviation, boating, decorative applications and refrigeration.

The Dow Chemical Company supplies the following listed properties as being representative of "Styrofoam," but they are not to be considered as specifications:

Density range (lbs./cu. ft.)	1.3-2.0
Compressive strength (psi at 1.55 density)	35.0
Compressive modulus (psi at 1.55 density)	1000.0
Bending modulus (psi at 1.55 density)	1900.0
Tensile strength (psi at 1.55 density)	100.0
Impact strength (⅜" x ½" specimen, lbs.)	3.8
Dielectric constant (1,000 c.p.s.)	1.00 plus
Power Factor (1,000 c.p.s., %)	0.002 plus
Permanent compressive load (Maximum psi at 1.8 density)	20.0
Thermal Conductivity	
K-Fastor (Mean temperature of 70° F Btu/sq. ft./hr./°F/in. A.S.T.M. guarded hot plate method C177-42T	0.27

Reference

"An Expanded Polystyrene," by D. W. McCuaig and O. R. McIntire, *Modern Plastics*, p. 106 (March, 1945).

Various "figure 8" core materials have been made of paper, cotton- or glass-reinforced plastic sheets. These materials are formed into an S-shape or figure 8 during the curing cycle. They are then cut in sections so that the edges support skins in a sandwich construction. Experimental production of glasscloth honeycomb material is now carried on by:

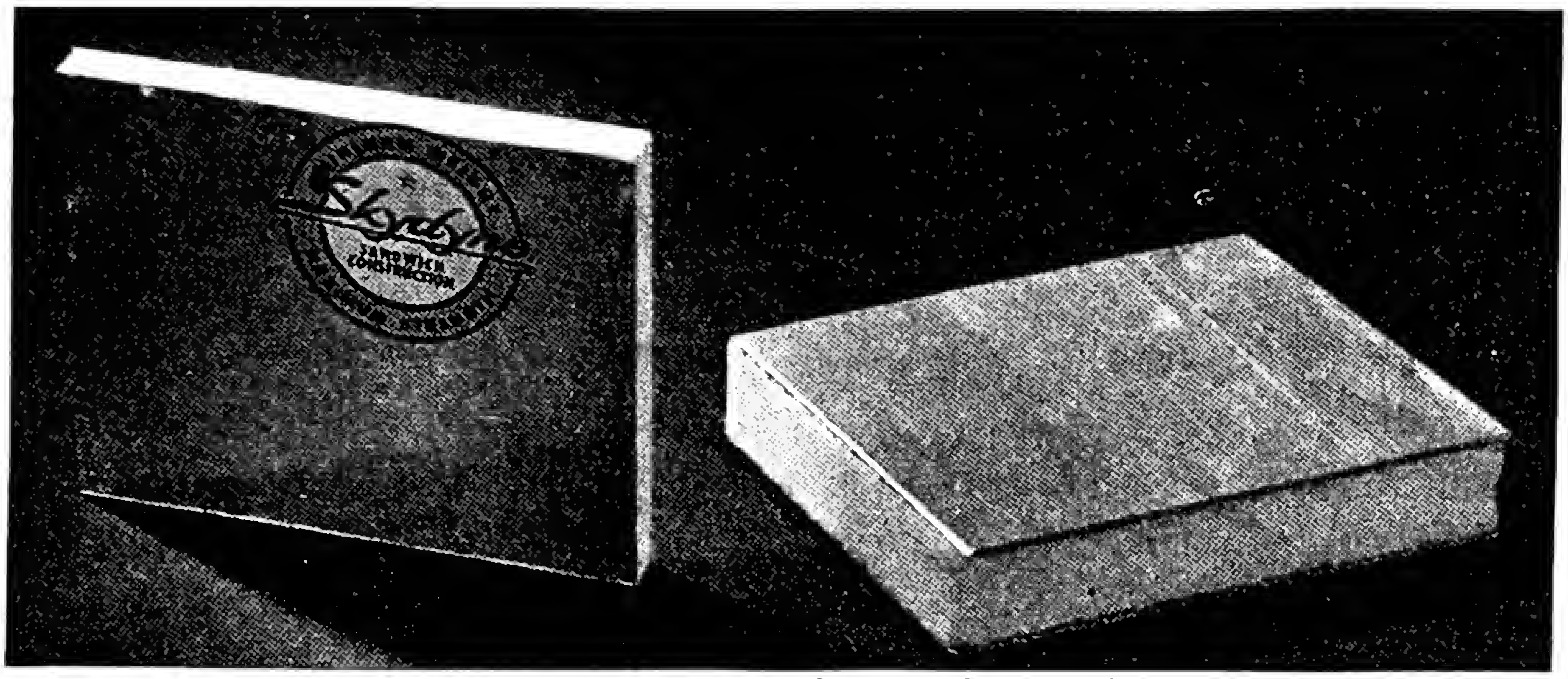
Western Products, Inc., 160 Essex St., Newark, Ohio.

Reference

"Honeycomb Core in Sandwich Structure," by L. S. Meyer and J. C. Chase, *Modern Plastics*, p. 136 (July, 1945).

Other sandwich structures are supplied by:

Skydyne Sales Co., 80 Broad St., New York 4, N. Y.
U. S. Plywood Co., Beechwood Ave. and 2nd St., New Rochelle, N. Y.



Courtesy Skydyne Sales Co., New York, N. Y.

FIGURE 37. Sandwich panels made with sheet aluminum faces and light weight core materials of balsa and cellulose acetate.

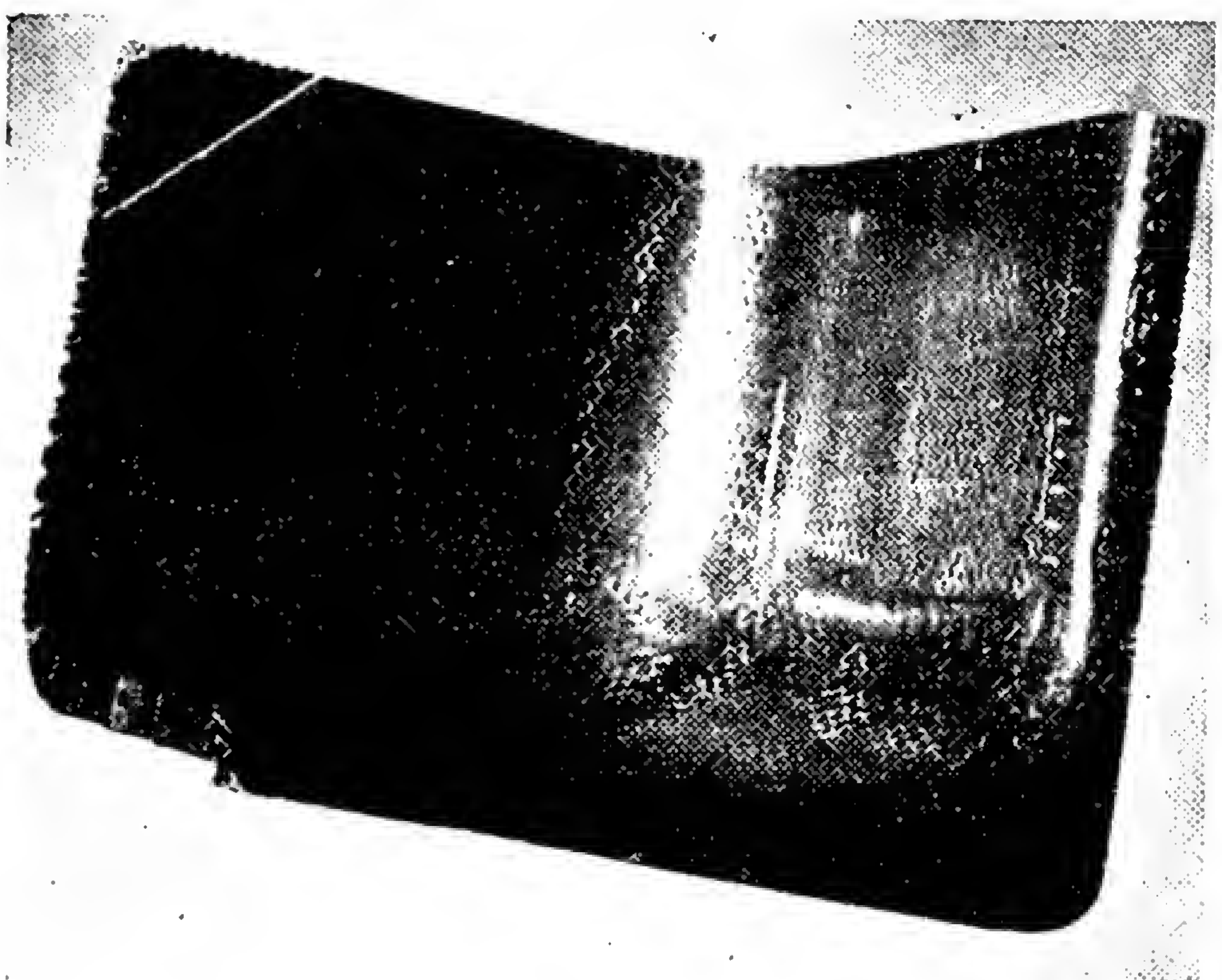
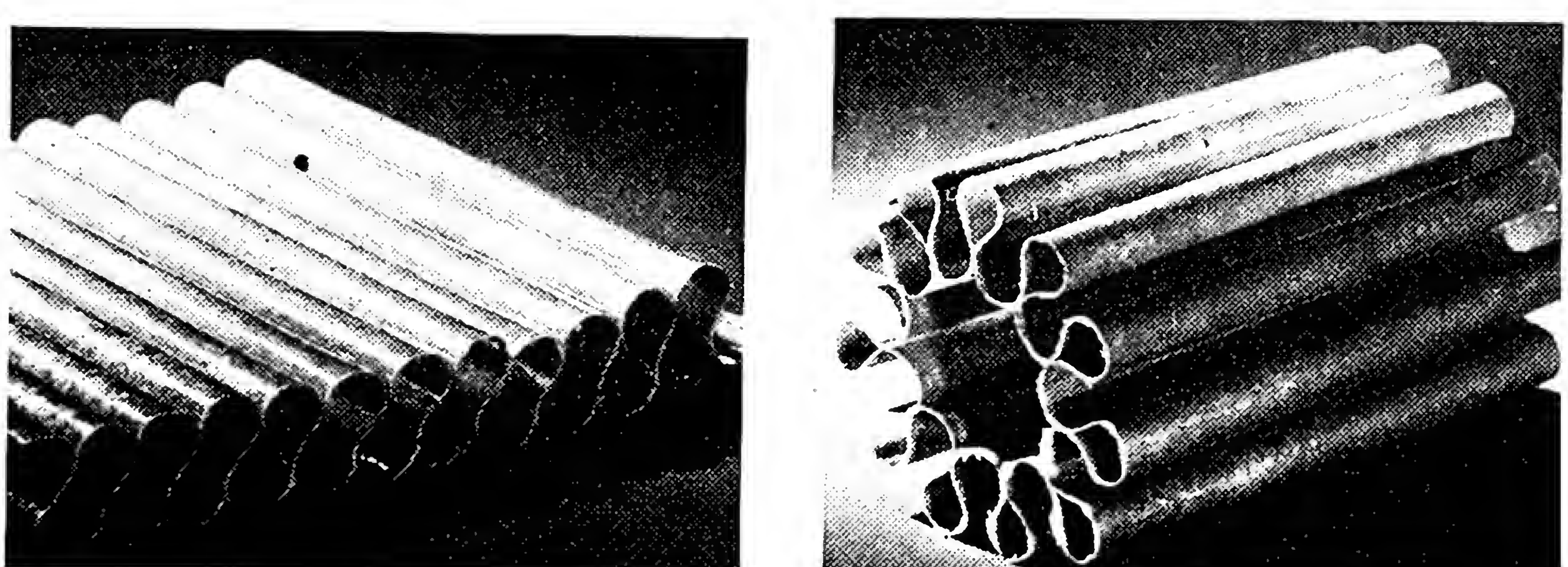


FIGURE 38.
Corner section of a lightweight sink for airplanes. Note honeycomb core between skins of glass cloth reinforced laminate.



Courtesy Cycleweld Div., Dodge Motors Co., Detroit, Mich.

FIGURE 39. Laminated core material made of glass cloth and resin in the shape of a figure eight. Paper or other reinforcing material may be used.

A new lightweight metal-faced sandwich material called "Metalite" has been developed by the Chance Vought Aircraft Division of United Aircraft Corp., Stratford, Conn., designer and builder of the Corsair fighter plane. This material is said to solve the two factors of wrinkling and parasite drag, which have reduced the efficiency of the modern laminar airfoil. A balsa core is used between thin sheets of high strength aluminum alloy. Moderate heat and pressure are used to accomplish the bonding.

A recent practical application for a sandwich construction of a balsa wood core with Fiberglas reinforced plastic skins is found in *icer trays* produced by.

The Baker-McMillen Co., 134 E. Miller Ave., Akron 1, Ohio

The inside dimensions of these trays are 22″ x 28″ x 7″. Use of these trays for display of fruit and vegetables results in a material reduction of the melting time of crushed ice. They are light in weight, easy to carry or handle, are strongly made and hard to damage. One grocery chain reports that these trays in test stores have cut their spoilage 80 per cent. For a chain of 60 stores it is estimated that spoilage elimination would save $1,000.00 a week.

Sandwich type structures with high strength-weight characteristics are finding a definite place in the future plans of design engineers. The Powell Calculator has been developed by Preston Laboratories, Butler, Pennsylvania. With its four dials and graduated indicator this calculator enables the sandwich designer to associate and determine several parameters involved in the Euler column formula. Certain parameters are eliminated by preliminary calculation, after which the calculator reaches a solution rapidly. Provision is also made for determining sandwich density of panel areas. This weight per square foot value facilitates the determination of the strength-weight efficiency of any particular design.

Reference

Instruction Manual on the "Powell Strength-Weight Calculator for Flat Sandwich Panels," published by Owens-Corning Fiberglas Corporation, Research Laboratories, Newark, Ohio (1946).

Chapter 5
Properties of Plastics

The physical properties of plastics include the following:

- Cold flow
- Compressive strength
- Distortion under heat
- Flexural strength
- Hardness
- Impact strength
- Linear coefficient of thermal expansion
- Modulus of elasticity in compression, in flexure and in tension
- Refractive index
- Softening point
- Specific gravity
- Specific heat
- Tensile strength
- Thermal conductivity

Compressive strength is computed from the load at the point of collapse when a sample is compressed in a testing machine. It is expressed in pounds per square inch (psi). The value usually decreases with a rise in temperature. The modulus of elasticity in compression is found from the slope of the stress-strain curve.

Flexural strength is a measure of fiber stress at the load value which causes failure. It is an indication of the resistance to twisting. The value usually decreases with a rise in temperature. Under a continuous load the flexural strength decreases with time. This test is really a combination measure of tensile and compressive strengths, because one part of the test sample is under tension and one part is under compression.

The modulus of elasticity in flexure is found from the slope of the stress-strain curve. Up to a certain point, called its "elastic limit," a plastic stretches under tension or compression and returns to its original state. The ratio of stretch to the load applied is called "modulus of elasticity in flexure." As the modulus of elasticity goes up, a greater load is required to deform a plastic, or it becomes more rigid, *i.e.*, resisting the stretch.

Physical properties of plastics are important in many applications. For structural components in aircraft certain mechanical properties are very important. These include static tensile, compressive, stiffness, bending properties and fatigue characteristics.

Data obtained from stress-strain curves are useful for design purposes. The knowledge of the creep and time-fracture properties of plastics would make possible more efficient use of these materials. Preliminary data show that thermosetting materials are able to sustain continuous dead-loading for a much longer time without failure than is true for thermoplastics. Higher bearing strengths are exhibited by laminated thermosetting plastics than by thermoplastics.

The physical properties of thermosetting resins are affected by the curing cycle. Early work in tooling for aircraft plants made use of the liquid casting resins. Phenolic casting resins were used for draw-die applications which required changes of tooling as structural changes were necessitated by combat experience.

The testing of plastics is a comparatively new field in the testing of materials. Test procedures and specimens have not been standardized.

Hardness is often reported in Brinell or Rockwell values. It is not a measure of surface hardness or resistance to scratching. The values for various other materials should be compared for proper interpretation of the results.

A convenient method available to check the completeness of curing of resins by means of hardness is by use of the Barco impressor. This is manufactured by:

Barber-Colman Company, Rockford, Illinois

Impact strength is a measure of the energy absorbed in breaking test bars by a single blow by a hammer mounted as a pendulum. It is the ability to resist blows. The "Izod" bar is held vertically while the "Charpy" bar is supported horizontally during such a test. The value is customarily expressed as "foot-pounds (of energy absorbed) per inch of notch." For example, a bar which is 0.250 inch wide on its notched face and which absorbs 0.50 foot-pound in breaking would be reported as having an impact strength of 0.50 divided by 0.250, or 2.00 "foot-pounds per inch of notch." The more energy consumed in breaking a sample the higher the value of impact strength.

It has been asserted that the present tests of impact strength as done by the Izod or Charpy methods give fictitious results which are not in agreement with the realistic experience of usage. For

example, one knows that a glass rod or window pane has a certain impact or breaking strength. When one notches or scratches the glass, a blow of much *less* intensity is required to break it. The test values obtained on "scratched" glass are not representative, and similarly it is contended that test values on "notched" samples of reinforced plastics are not very reliable as a true guide. It is probable that effort will be devoted to the development of better tests for impact strength.

Linear Coefficient of Thermal Expansion is a measure of the increase in length of a plastic with a rise in temperature. For materials of greater dimensional stability, like glass reinforced plastics, this value is low.

Specific gravity of a substance is found by comparing the weight of any given volume of the substance with the weight of an equal volume of water.

Substance		*Specific Gravity*
Contact pressure resin alone	average value	1.3
Paper (wood pulp) and resin laminate		1.4
Cotton cloth and resin laminate		1.4
Glass cloth and resin laminate		1.7
Reinforcing Materials Without Resins:		
Paper (wood pulp)		1.5
Cotton cloth		1.5
Glass cloth		2.4

Tensile strength is the "load" in pounds per square inch of cross section necessary to cause failure of the plastic test piece. It is the ability to resist being torn apart. The tensile strength of all plastics varies inversely with temperature. They show fatigue when subjected to repeated stresses. When comparing tensile strengths of two different plastics, the "rate of elongation" must be the same in all tests. Usually the tensile strength of a plastic decreases both with a rise in temperature and with an increase in moisture content. The molding technique and the reinforcing materials used also affect the tensile strength.

Modulus of Elasticity in Tension. By definition the *slope* of the stress-strain curve at any point is the "tangent modulus of elasticity."

Chemical Properties of plastics include resistance to moisture absorption, to chemical reagents and combinations of conditions which may affect the structure of the laminate—both resin and reinforcing agent (see Figure 40).

One report has shown the following comparative figures for water absorption by laminates made with glass, paper and cotton:

Reinforcing Agent	*Water Absorbed*	*Resin*
Glass cloth OC-64	1.0%	Phenolic
Paper	5.1%	Phenolic
Cotton	8.6%	Urea
Glass cloth OC-64 (Wright Field Report)	0.4%	—

As the laminating pressure is increased from 10 to 100 psi the moisture absorption of cotton- and paper-reinforced laminates de-

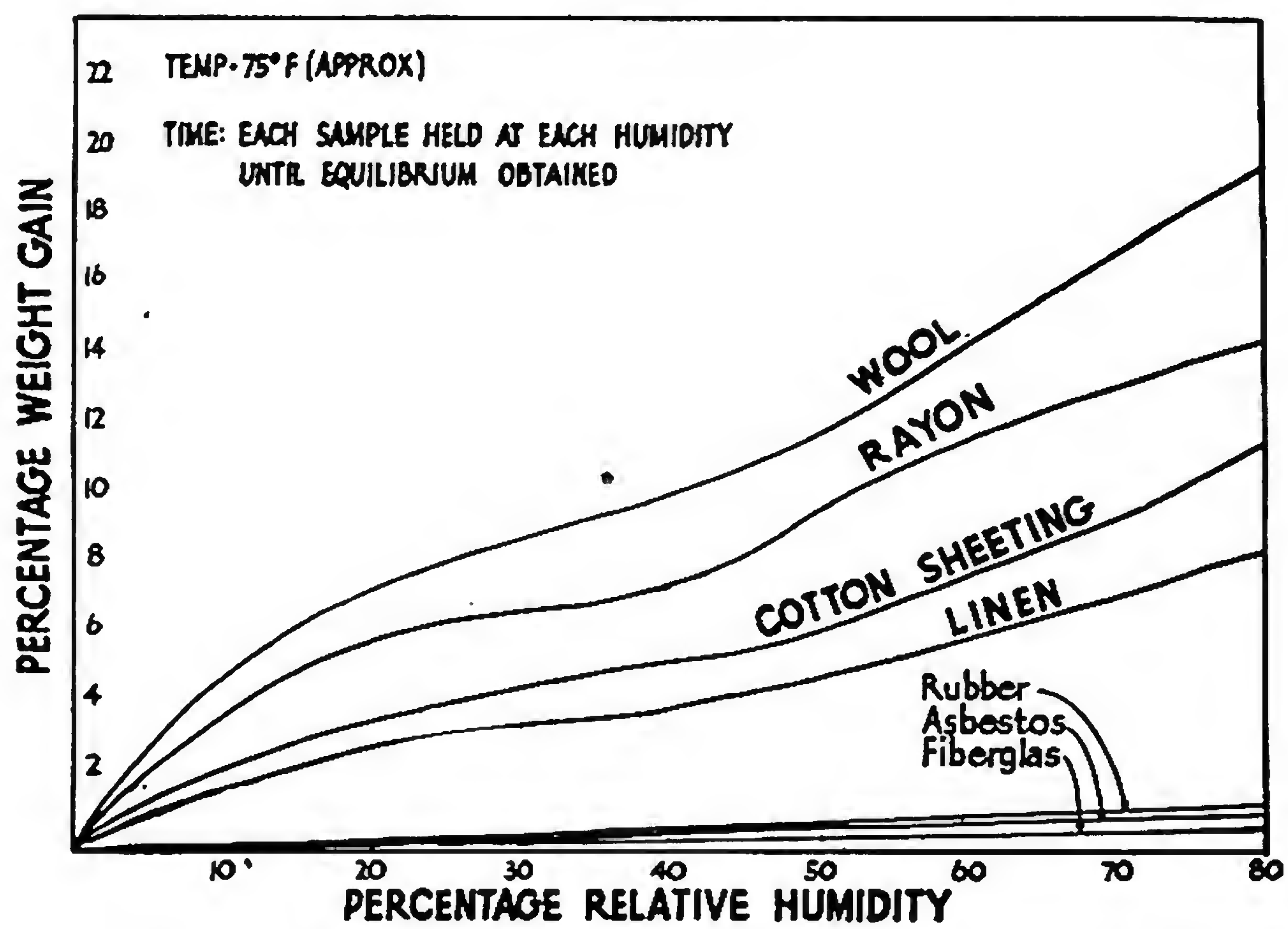


FIGURE 40. Moisture adsorption of Fiberglas and other materials *versus* relative humidity.

creases from 14 to 7 per cent for cotton and from 9 to 4 per cent for paper. This quality varies also with the nature of the *resin* and of the reinforcing material.

The absorption of moisture causes organic materials to swell, and to shrink when they dry. Obviously, this affects the dimensional stability of plastics products in which they are employed as reinforcement.

Moisture Absorption of Reinforcing Materials at 75° F.

	40% Relative Humidity	*80% Relative Humidity*
Glass fibers	0.2%	0.4%
Asbestos	0.4	0.8
Rubber	0.5	1.0
Linen	4.0	8.5
Cotton	5.2	11.6
Rayon	7.6	14.5
Wool	10.2	19.6

The many diversified types of resins give a large variety of chemical properties which one finds in the resulting laminate.

References

"Resistance of Plastics to Chemical Reagents," by John Delmonte, *Plastics*, p. 36 (Nov., 1945).

"Heat Resistance of Laminated Plastics," by E. O. Hausmann, A. E. Parkinson and G. H. Mains, *Modern Plastics*, p. 151 (Nov., 1944).

"Physical Properties of a Structural Plastic Material," by Cecil W. Armstrong, *Trans. Am. Soc. Mech. Eng.*, **66**, 135 (1944).

The resins have various properties insofar as resistance to fire is concerned. The phenolics are fire-retardant in nature, whereas the polyesters support combustion. A reinforced plastic may be more or less fire-resistant depending on the resin and the reinforcing material used. Civil Air Regulations are becoming more strict and rigid in the interest of protecting occupants of planes from fire hazards. Inquiries should be directed to the resin manufacturer regarding the material he supplies.

"Flame-resistant" has been defined as referring to materials which will not support combustion to the point of propagating a flame after removal of the ignition source.

"Flash-resistant" has been defined as referring to materials which will not burn violently when ignited.

Reference

"Fire Hazards of the Plastics Industry," Report No. 1, National Board of Fire Underwriters, 85 John Street, New York, N. Y. (1946).

The following resins have been reported to be fire-retardant or self-extinguishing in contrast with the rather flammable polyester resins used for laminating.

BCM Resin with vinylite added, supplied by E. I. duPont de Nemours & Co., 626 Schuyler Ave., Arlington, N. J.

Marco Resin MR-17-D, supplied by Marco Chemicals, Inc., Sewaren, N. J.

Monsanto #541, supplied by Monsanto Chemical Co., Springfield 2, Mass.

Plyophen 110-L-96, supplied by Reichhold Chemicals, Inc., 601 Woodward Heights Blvd., Detroit 20, Mich.

Selectron 5012 and *5041*, supplied by Pittsburgh Plate Glass Co., Paint Div., Grant Bldg., Pittsburgh 19, Pa.

It should be mentioned that some fire-retardant compatible agent is usually added to the resin. Such agents include tricresyl phosphate, vinylite resins and antimony oxide.

Testing properties of plastics may be done in one's own laboratory or by commercial testing laboratories such as:

A. D. Little, Inc., Cambridge, Mass.
Pittsburgh Testing Lab., Pittsburgh, Pa.
Plastics Industries Technical Institute, Los Angeles, Calif.
U. S. Testing Co., Hoboken, New Jersey.
Wilmington Testing & Research Labs., Wilmington, Del.

Testing machines for tension, compression, flexure and other data may be obtained from a number of companies. Some of these firms are:

American Machine and Metals, Inc., Riehle Testing Machine Div., East Moline, Ill.

Atlas Electric Devices Co., 383 West Superior St., Chicago, Ill.

Baldwin-Southwark Div. of the Baldwin Locomotive Works, 940 Simpson St., Eddystone, Pa.

Central Scientific Co., 456 East Ohio St., Chicago, Illinois.

Taber Instrument Corp., 115 Goundry St., North Tonawanda, N. Y.

Tinius Olsen Testing Machine Co., Philadelphia 23, Pa.

For details of testing methods and specifications the reader is referred to standards set up by the American Society for Testing Materials, Committee D-20, in a book "A.S.T.M. Standards on Plastics." Such a volume is usually available in technical libraries or may be obtained from:

American Society for Testing Materials, 260 S. Broad St., Philadelphia 2, Pa.

A second reference on this subject is the Federal Specification L-P-406a, entitled "Plastics, Organic: General Specifications, Test Methods," which is priced at $0.15 and for sale by the:

Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

It should be pointed out that a very complete compilation of data on the properties of plastics may be found in the 1946 edition of "Modern Plastics Encyclopedia" and accompanying charts. This book is published by:

Plastics Catalogue Corp., 122 East 42nd Street, New York 17, N. Y.

References

"Basic Physical Properties of Laminates," by Philip M. Field, *Modern Plastics*, p. 91 (August, 1943).

"Physical Properties Explained," by Warren V. Prince, *Tool & Die*, p. 1 (July, 1944).

Flaws in plastics laminates may be detected by use of a new device called the hypersonic analyzer. Its operation is based on the use of sound waves of a frequency inaudible to the human ear. Both changes of density and a change in the modulus of elasticity are detected. Thus poor bonding between the reinforcement and the resin can be located when x-ray pictures show no indication of weakness. This apparatus is supplied by:

Brush Development Co., Cleveland, Ohio.

Chapter 6

Illustrations of Laminating Tank Cover, Boat Deck, and Milk Bottle Case

Tank Cover

A cover made for a tank illustrates many of the versatile handling properties of low-pressure laminating. A light-weight, strong and non-denting removable cover was required. The finished tank cover, which is shown in Figure 43, is 4 ft. 9 in. in diameter, and has an 18-inch hole in the center. This hole is reinforced with a wooden ring insert to facilitate attachment of another piece and to improve the stiffness of the thin reinforced plastic cover. The cover was made of resin, cloth, and a wood ring.

The resin used was extremely viscous and was applied to the cloth with a knife coater. Many of the thermohardening polyester resins are inhibited during cure by air, but this resin cures to the same hardness in air as in its absence. The resin is very viscous at room temperature, but at the curing temperatures it thins out somewhat, though not enough to flow excessively.

The male mold was made of wood at a total cost of $75.00. It was sufficiently high that there was 1 inch of wood below the trim line of the plastic. The mold surface was sealed to prevent the transmission of water from the wood into the plastic and to prevent the resin from going into the voids in the mold surface during cure.

Because of the continuous convex curvature of the mold it was possible to use low-pressure resins and mold this piece without pressure. Unlike many high-pressure resins, the resins of the thermohardening polyester group are adaptable to casting techniques. When pressure is used, one of its main functions is to densify the filler so that the finished laminate will contain a high percentage of the relatively high-strength filler. Where a mold with a continuous convex molding surface is available, the effect of pressure in densifying the filler can be approximated by stretching the top ply of the plastic assembly and tacking the edges securely to the edge of the mold. Cloth is more easily adapted to this method of molding

FIGURE 41. Plastic dome for gas tank; approximately 4 ft. 9 in. in diameter.

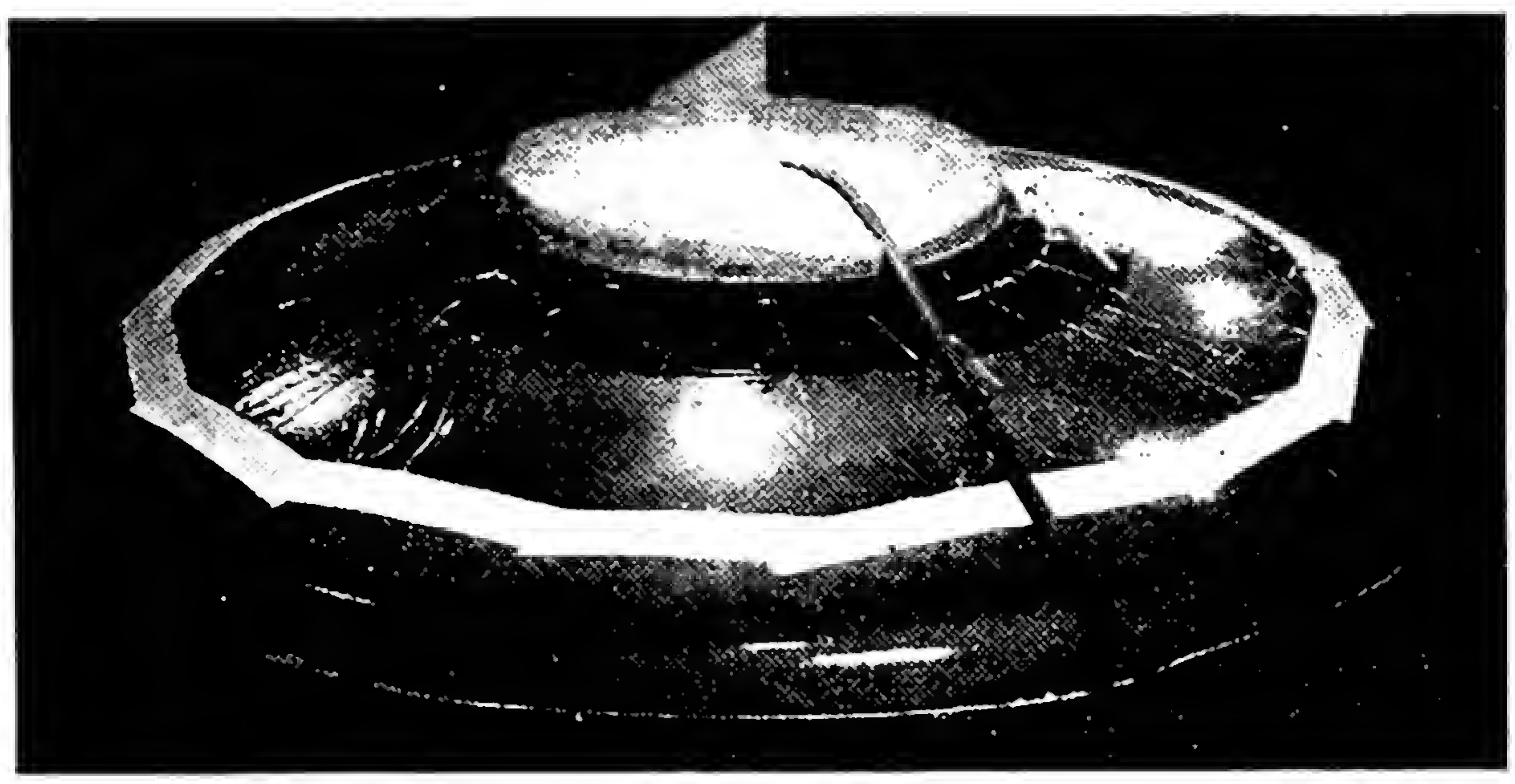


FIGURE 42. Plastic dome for gas tank ready for second step in curing. Note insulation over center portion to prevent curing of resin.

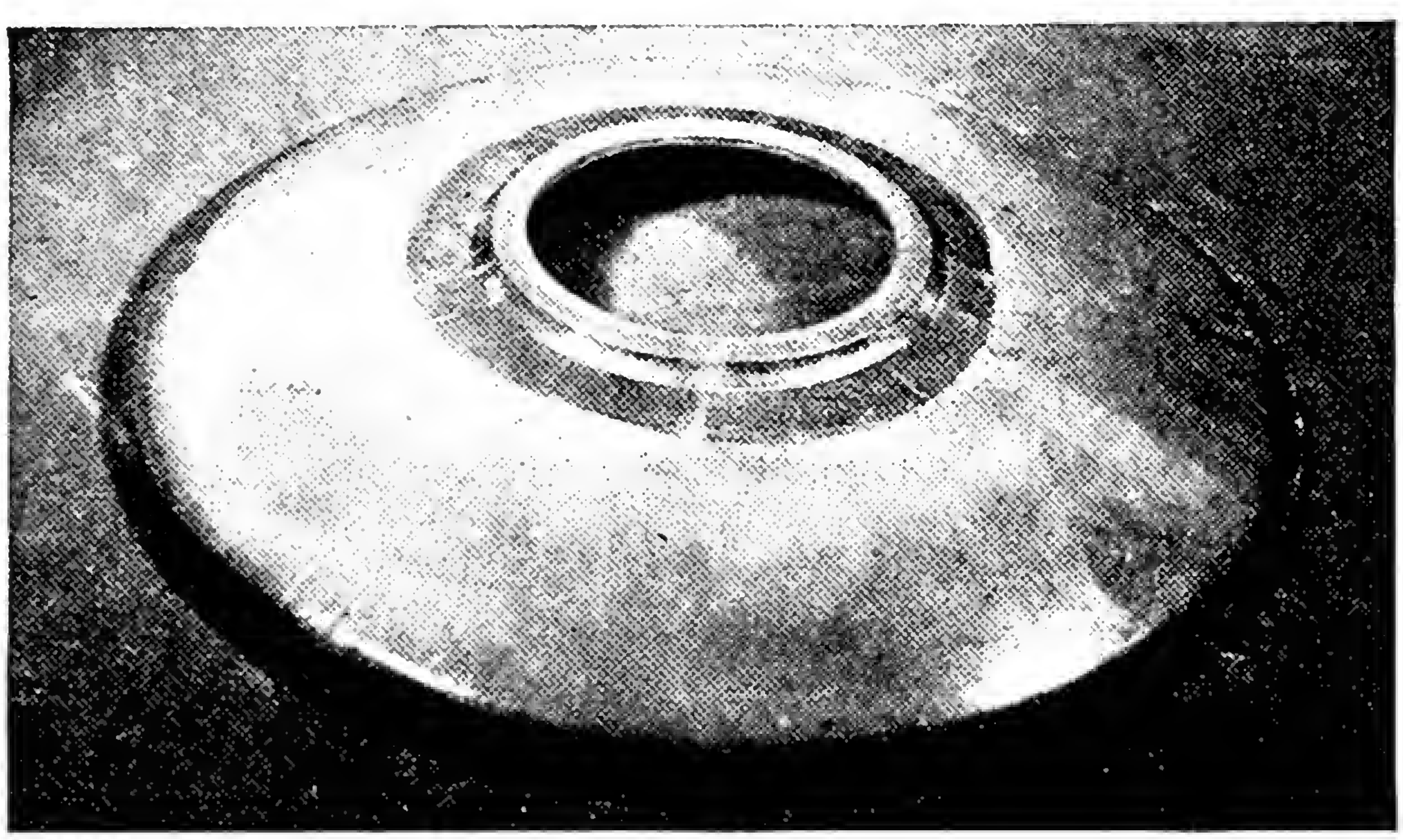


FIGURE 43. Completed plastic tank dome with wooden reinforcing ring in the center.

than mat products, because in the form of cloth the reinforcement is already in a densified form.

In parallel-laminated cloth laminates, strength in the 0° (warp) and 90° (fill) directions are high, while strengths in the 45° direction are considerably lower. In the tank cover a fairly round strength pattern was desirable, and it was obtained by "rotating" the warp direction of the cloth in the lay-up of successive plies.

Where rotation of plies is used in the lay-up, there is the possibility of warpage in the finished piece unless the rotation is symmetrical about the neutral axis. A balanced lay-up of square-woven cloth rotated to compensate for the weak 45° angle might have the warps of successive layers at 0°, 30°, 60°, 60°, 30° and 0°. For unidirectional cloth the rotation must be on the basis of 180°, as: 0°, 60°, 120°, 60°, and 0°.

The steps involved in the fabrication of the tank cover shown in Figure 43 were as follows:

(1) The wood mold surface was sealed.

(2) Resin-impregnated cloth was placed on the mold. Successive layers were rotated to give a round strength pattern, and the rotation was symmetric.

(3) The last ply of cloth was made of two 38″ widths of cloth stitched together to form one piece covering the entire plastic assembly. This top ply was stretched taut and stapled to the bottom of the mold.

(4) The plastic assembly was given a slow cure so that excess resin from the under layers of cloth saturated to the top ply, making it an integral part of the tank cover.

(5) The tank cover was removed from the mold and rough-trimmed (see Figure 41). An 18″ hole was cut out of the center.

(6) A wooden ring insert was positioned on top of the tank cover. The inside diameter of the wooden ring was 18″. The outer edge of the ring tapered to a feather edge.

(7) Discs of resin-impregnated cloth were placed over the wooden ring concentric with it. These rings were about 26″ in diameter.

(8) A polyvinyl alcohol (PVA) disc was placed over the cover and the edges of PVA disc were sealed to the cover with adhesive tape. Another PVA disc was secured to the underside of the tank in a similar manner, and the assembly was placed on the wooden mold.

(9) The air in the space between the two PVA discs was exhausted by means of a truck tire valve connection through the upper disc. The core

had to be removed from the tire valve stem to permit this reverse passage of air through it.

(10) A 19″ disc of insulation was placed over the assembly concentric with the wooden ring insert, and the assembly (shown in Figure 42) was placed under a bank of infrared lights. The heat from the infrared lamps cured the exposed plastic to bond the discs to the top surface of the tank cover. The resin that was protected from the heat of the lamp by the insulation remained uncured.

(11) The tank cover was taken from the mold and the two PVA discs removed.

(12) The cloth discs in the uncured resin area were cut radially from the center outward, giving triangular segments which were then folded back against the under surface of the tank cover. The tips of the segments were cut off and the folded back area was surfaced with one layer of cloth to dress up the surface.

(13) The PVA discs were again attached to the cover as described in (8). A vacuum was drawn and the remaining resin was cured in a hot air oven.

(14) After trimming the outer edge to dimensions, the tank cover was complete.

Boat Deck

The methods used to make a plastic boat deck illustrate the versatility of plaster of paris as a mold material and show how readily plastic pieces can be ribbed for stiffening by low-pressure molding procedures.

The ease of ribbing facilitates prototype work because a prototype can be made without ribs and tested for strength. If the prototype is not sufficiently stiff and strong, ribs may be added and the piece retested. This procedure can be repeated until the prototype has a satisfactory performance. This approach to design work eliminates the need for a detailed stress analysis on the piece, and it is particularly useful when a table of the stresses to which the piece will be subjected is not available.

Figures 44 and 45 show a plastic boat hull being lifted from a plaster of paris boat deck mold. Figure 44 is a view taken underneath the inverted boat hull. The boat deck mold is contoured to approximate the conventional shape for a boat deck. Additionally, the edge of the plaster mold has been contoured so that a flange molded against this edge will provide a means of attachment

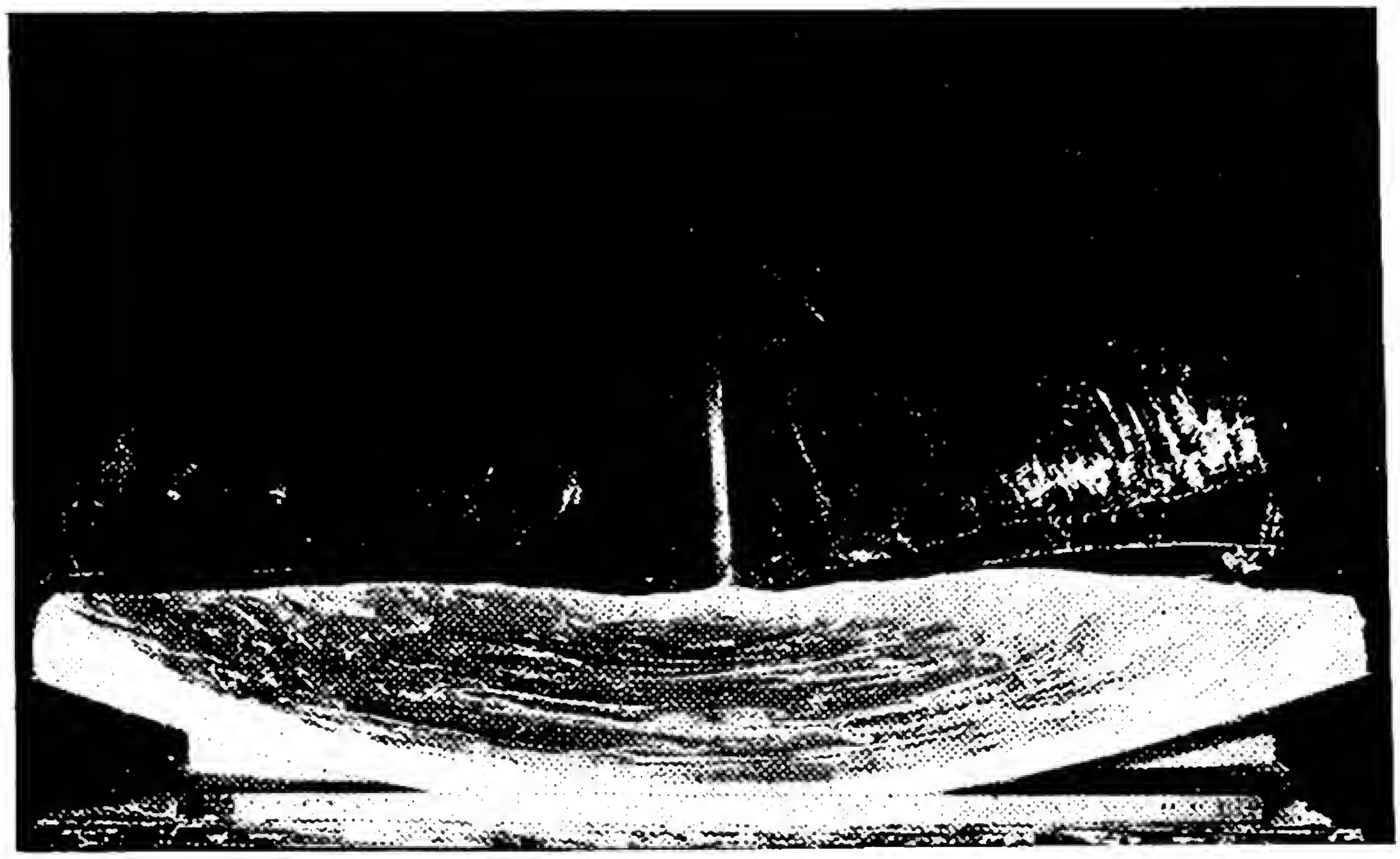


FIGURE 44. Plaster of Paris mold for boat deck.

FIGURE 45. Forming plaster of Paris mold for boat deck.

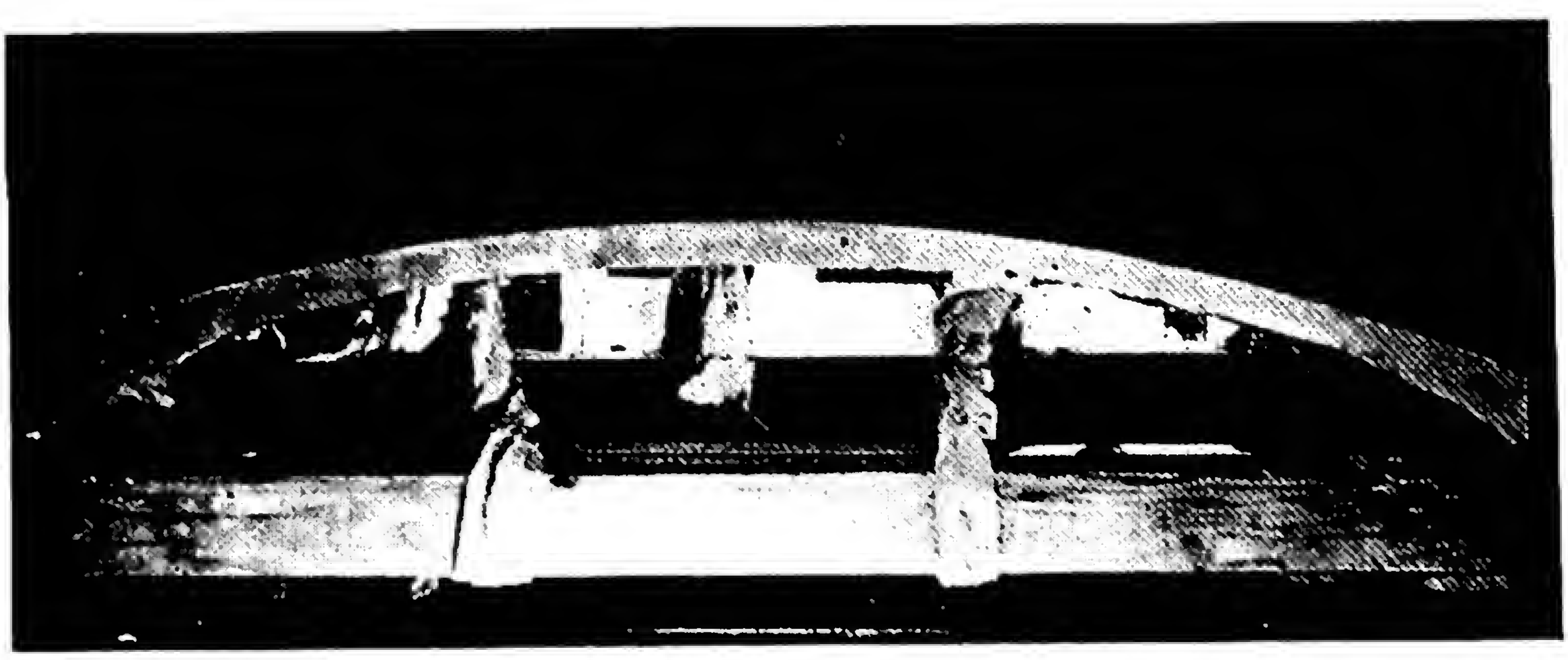


FIGURE 46. Plaster of Paris boat deck mold.

of the boat deck to the boat hull. A bump rail will cover the joint.

The steps involved in molding the the boat deck and in adding ribs are as follows:

(1) A piece of 16-gauge sheet metal was "broken" to approximate a pie-shaped section of the surface at the vertex of a cone. The "break" lines met at the prow and tapered to a 2″ spacing at the aft point of the deck.

(2) The sheet metal form was secured to a work table by the two plaster of paris footers visible in Figure 45.

(3) A molded boat hull was inverted and positioned over the piece of sheet metal so that the prow coincided with the junction of the "break lines.

(4) The boat hull was trimmed to the contour of the sheet-metal piece.

(5) Plaster of paris was cast on the sheet metal form. Along the edges where the plaster touched the boat hull, the thickness of the plaster was built up to about three inches to provide a generous plastic flange.

(6) The plastic boat hull was removed (see Figure 45).

(7) A framework of 2 x 4's was fastened to the plaster deck mold with plaster of paris and burlap strips.

(8) The mold was inverted to the position shown in Figure 46, and a strip of metal was fastened around the edge of the plaster section. This metal strip was the same thickness as the boat hull so that the flange molded on the deck would fit over the boat hull.

(9) The plaster surface was coated with a sealant.

(10) Plastic was built up on the mold, with resin-impregnated cloth used for all but the last ply. This top ply was made by sitching together two widths of cloth, and was not coated with resin to facilitate handling.

(11) The top ply of cloth was pulled tight over the convex curvature of the plaster mold and was stapled securely to the 2 x 4″ frame.

(12) The resin was cured in a hot-air oven with a slow curing cycle, during which some resin flowed outward from the under plies of cloth, impregnated the outer ply of cloth, making it part of the laminate.

(13) The boat deck was removed from the mold (Figure 47). Ribs were prefabricated. Hat section ribs $\frac{3}{4}''$ x $\frac{3}{4}''$ were selected as the shape and balsa was the core material. The high directional properties of balsa make it desirable in applications like this where the moisture take-up is likely to be small. Four strips of balsa $\frac{3}{16}''$ x $\frac{3}{4}''$ were laminated on the sheet-metal form with a cold-setting wood adhesive. A polyvinyl alcohol envelope and vacuum were used to hold the strips against the metal

plate while the adhesive set up. Figure 48 shows how the ribs were laminated to contour.

(14) The concave surface of the plastic boat deck was sanded in the areas where the flanges of the hat sections were to be attached.

(15) The laminated balsa ribs were positioned and 5" wide strips of cloth were placed over the ribs.

(16) The ribbed boat deck assembly was placed in a polyvinyl alcohol envelope.

(17) The assembly was cured in a hot-air oven using the resin manufacturer's recommendations of time and temperature (see Figure 49).

Milk Bottle Case

Many of the handling procedures of low-pressure molding are included in the fabrication of a milk bottle crate. This milk bottle crate also illustrates one type of application in which low-pressure molding may find considerable use in the future. A milk company converted from round to square bottles. These bottles nested more compactly, with the result that volume-wise 25 per cent more bottles could be loaded on a truck. However, weight-wise the truck was limited to approximately the same number of bottles. The plastic case weighed 4¼ lbs. as compared with 11½ lbs. for a wood-metal combination case, permitting a truck to carry a higher payload.

The resin used for the fabrication of this prototype was a thermo-hardening polyester resin. It had no volatile components and was not air-sensitive. The resin was very viscous and was applied to the cloth in a knife-coating operation. It had a high degree of self-tack, a property that was useful in the hand lay-up of this prototype. Since the cure of the resin was inhibited by rubber, a separator sheet of Cellophane was placed between the plastic and the rubber vacuum-tight cover sheet before curing.

This prototype was molded in an inverted position on account of the inserts and because a taper was required on the sidewalls for removal of the molded plastic piece from the mold. Figure 50 shows the mold used for this prototype. Made of wood, the mold was slotted to receive the molded-in bottle spacers. The photograph shows the mold surfaced with a layer of Cellophane and ready for use. It is mounted rigidly to a metal plate which extends well beyond the edge of the mold so that a formed, vacuum-tight cover sheet can be clamped readily to the plate. A hole through

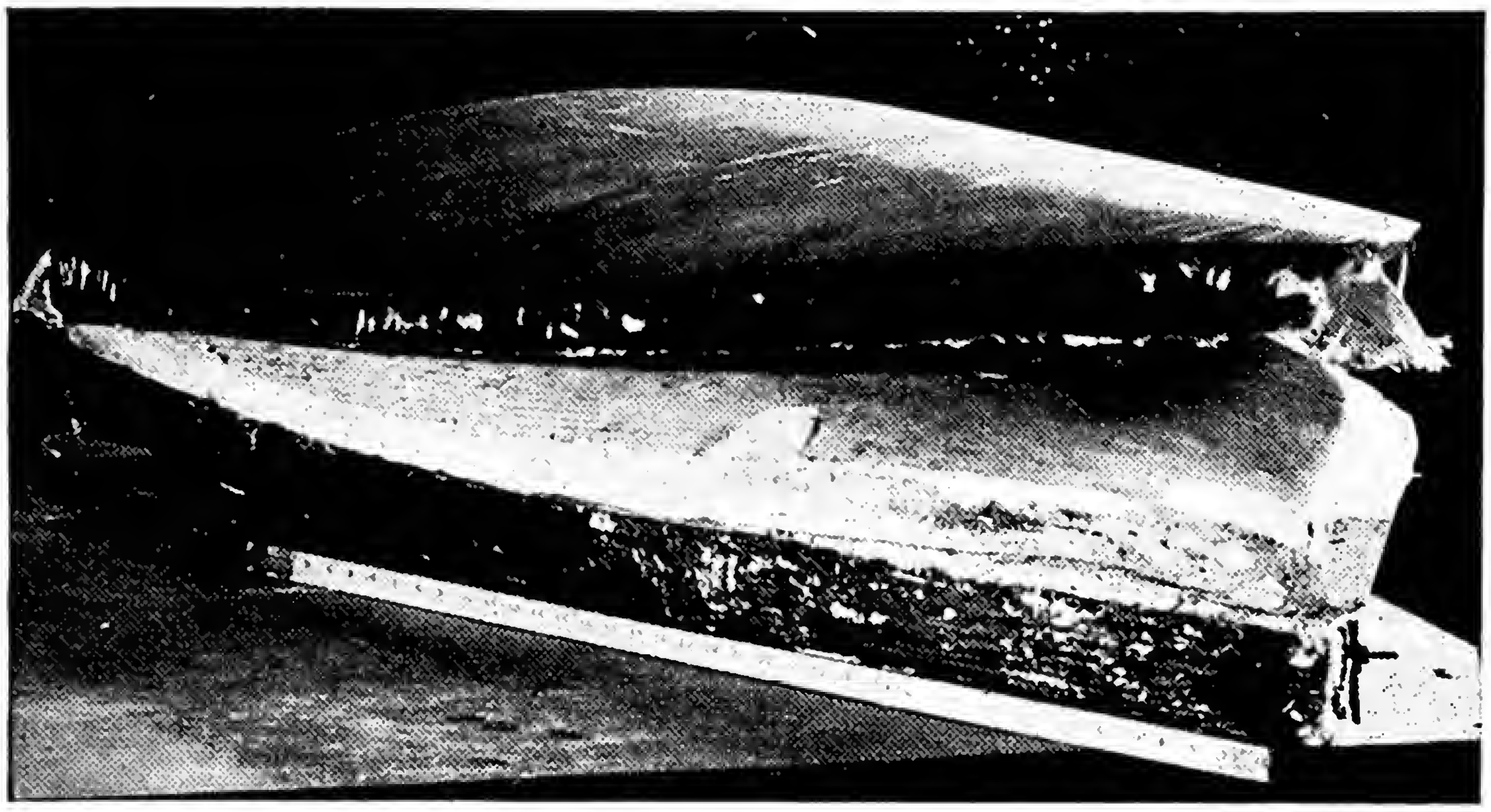


FIGURE 47. Reinforced plastic boat deck removed from plaster of Paris mold.

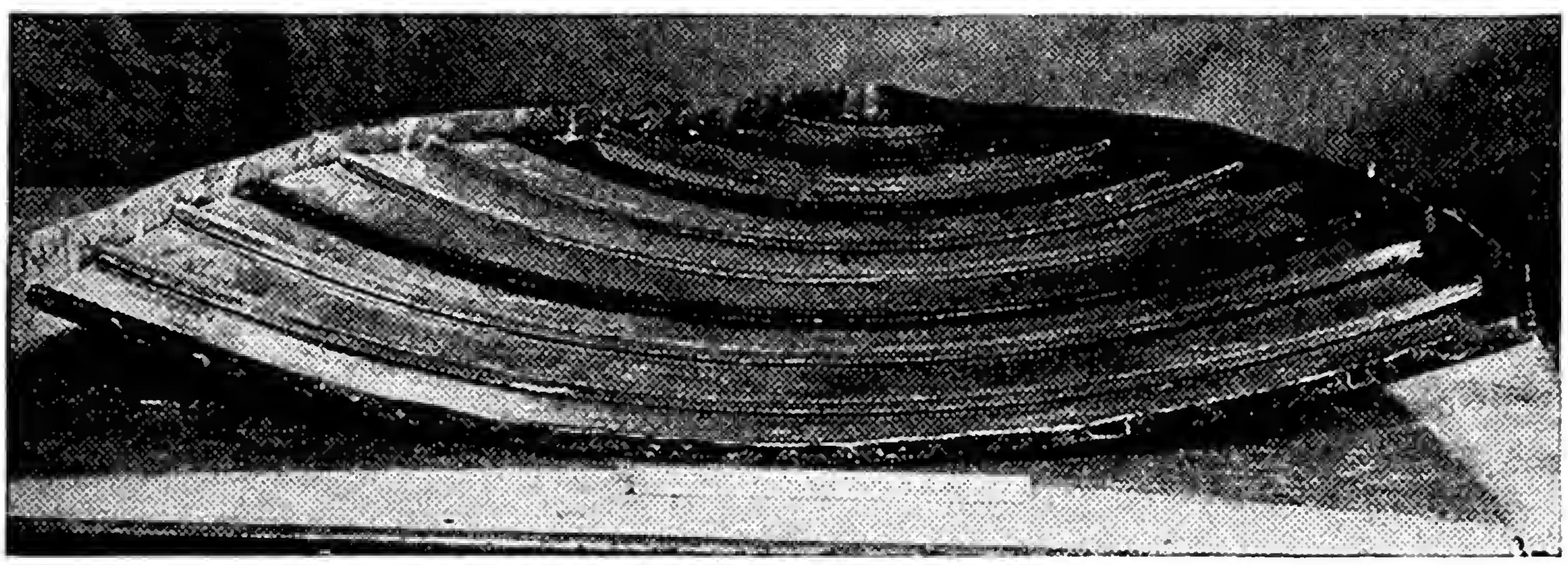


FIGURE 48. Laminating Balsa ribs for boat deck reinforcement.

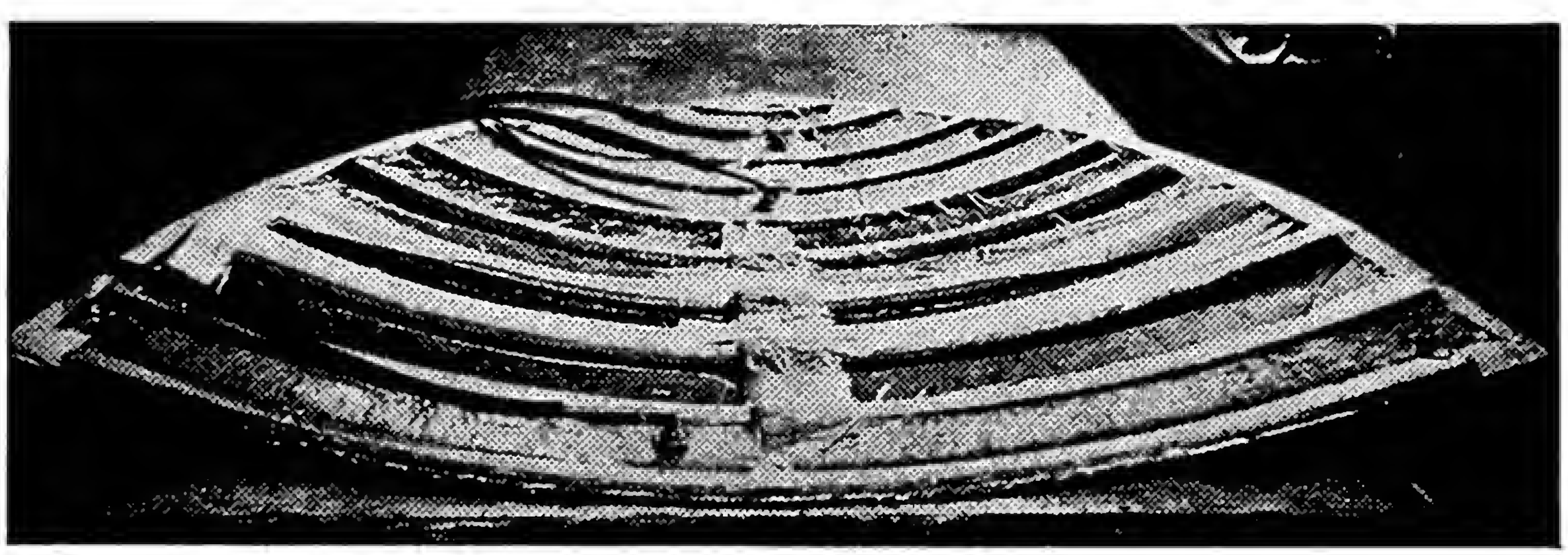


FIGURE 49. Completed plastic boat deck reinforced with Balsa ribs.

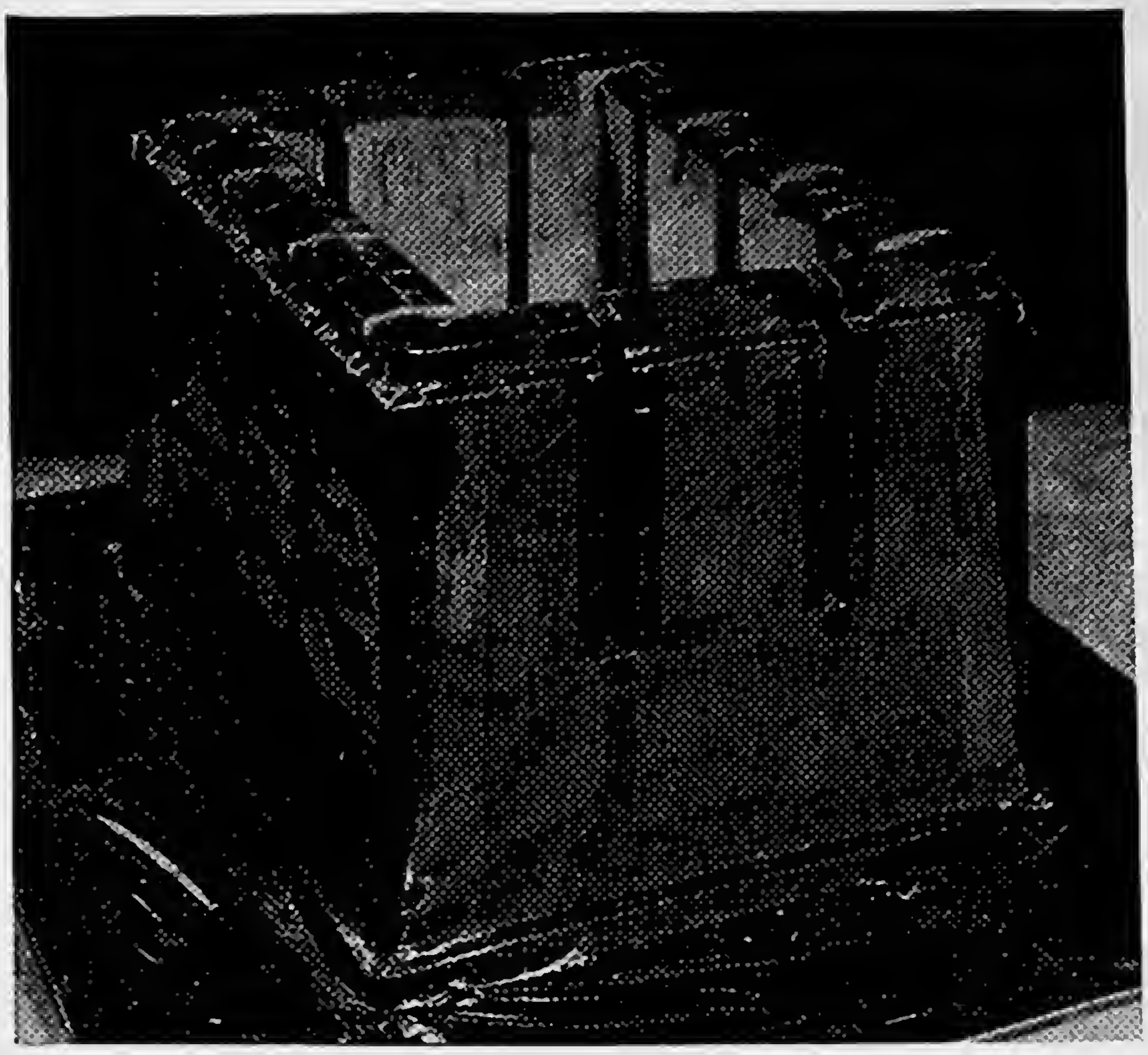


FIGURE 50.

A slotted, wooden mold for plastic milk bottle case.

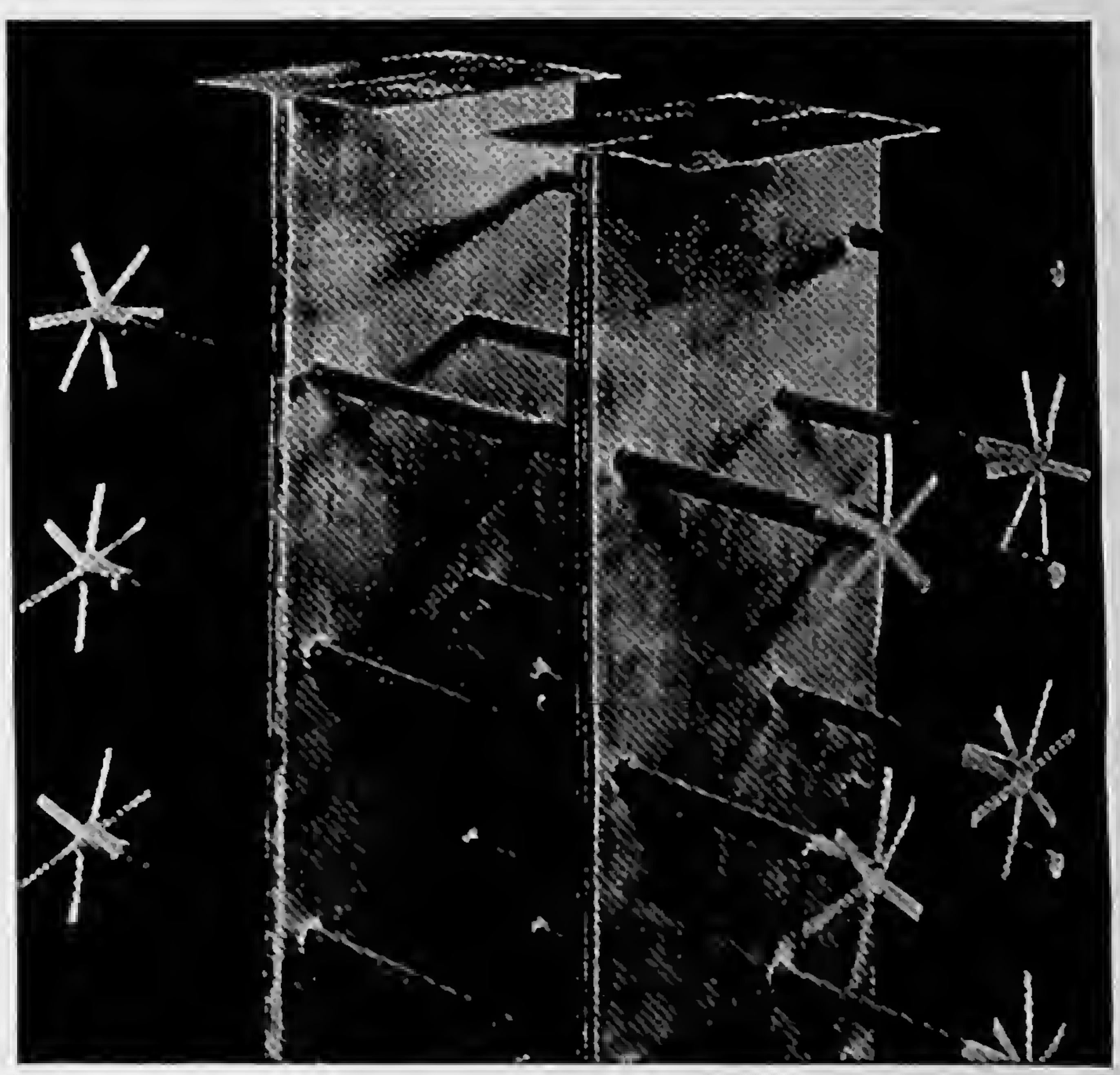


FIGURE 51.

Inside section for plastic milk bottle case.

FIGURE 52.

Spacer assembly placed in mold for plastic milk bottle case.

the metal plate is used for evacuating the mold during cure. A metal plate on the top of the mold engages the recesses in the top of the mold. A plate serves a dual purpose. It prevents the sides of the mold from deflecting inward under the vacuum used in molding and supports the vacuum cover sheet.

All the inserts shown in Figure 51 were prefabricated. The longitudinal members were made by parallel-laminating six plies of $\frac{1}{28}''$ veneer with resin-impregnated cloth. To further increase the stiffness of these members, they were surfaced with unidirectional cloth. In the same operation flanges were molded on the ends. Molds used for this were made of 16-gauge sheet metal. Channel-shaped molds were used for the sides and flat pieces of sheet metal were used for the ends. As shown in the photograph, the longitudinal spacers were drilled to receive the cross spacers.

The cross members were made by surfacing $\frac{1}{4}''$ wood dowel stock with unidirectional cloth. The spiders on the end of the dowels were made from sheet metal with tin snips and a soldering iron. In Figure 51 the six rods shown with these spiders act as spacers for the bottles. The four rods without visible methods of attachment on the end are bottle supports and during cure are tied into the beefed up section around the bottom of the case.

Figure 52 shows how this spacer assembly fits into the mold. In addition it shows how the two prefabricated members used to reinforce the top and bottom edges fit onto the mold.

The steps in the lay-up are as follows:

(1) The longitudinal spacers were positioned in the slots in the mold.

(2) The cross spacers and bottle rests were in place provided by the holes through the longitudinal spacers.

(3) A strip of cloth several inches wider than the height of the mold was wrapped twice around the mold.

(4) The rings for reinforcing the top and bottom of the milk bottle crate were positioned on the mold, and the excess cloth folded back over these reinforcements far enough to tie into the cloth in the body of the wrap.

(5) The plies of cloth were slit to allow the flanges on the ends of the longitudinal spacers to be pulled through to the outside.

(6) Holes were cut in the cloth at the proper places so that the spiders could be slipped over the round cross spacers, leaving the fingers outside the cloth.

(7) Two more wraps were made around the mold with resin-

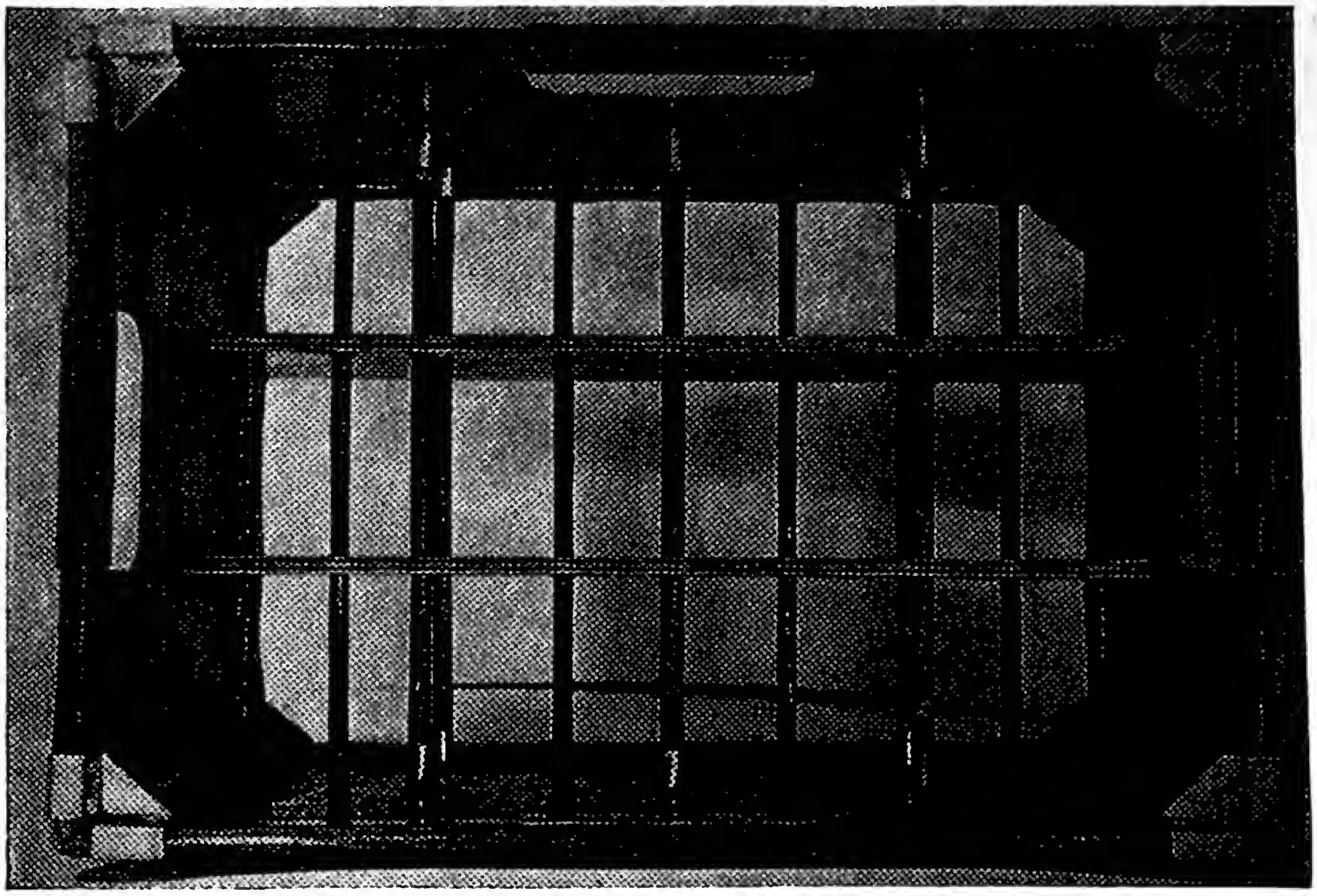


FIGURE 53. Top view of milk bottle case.

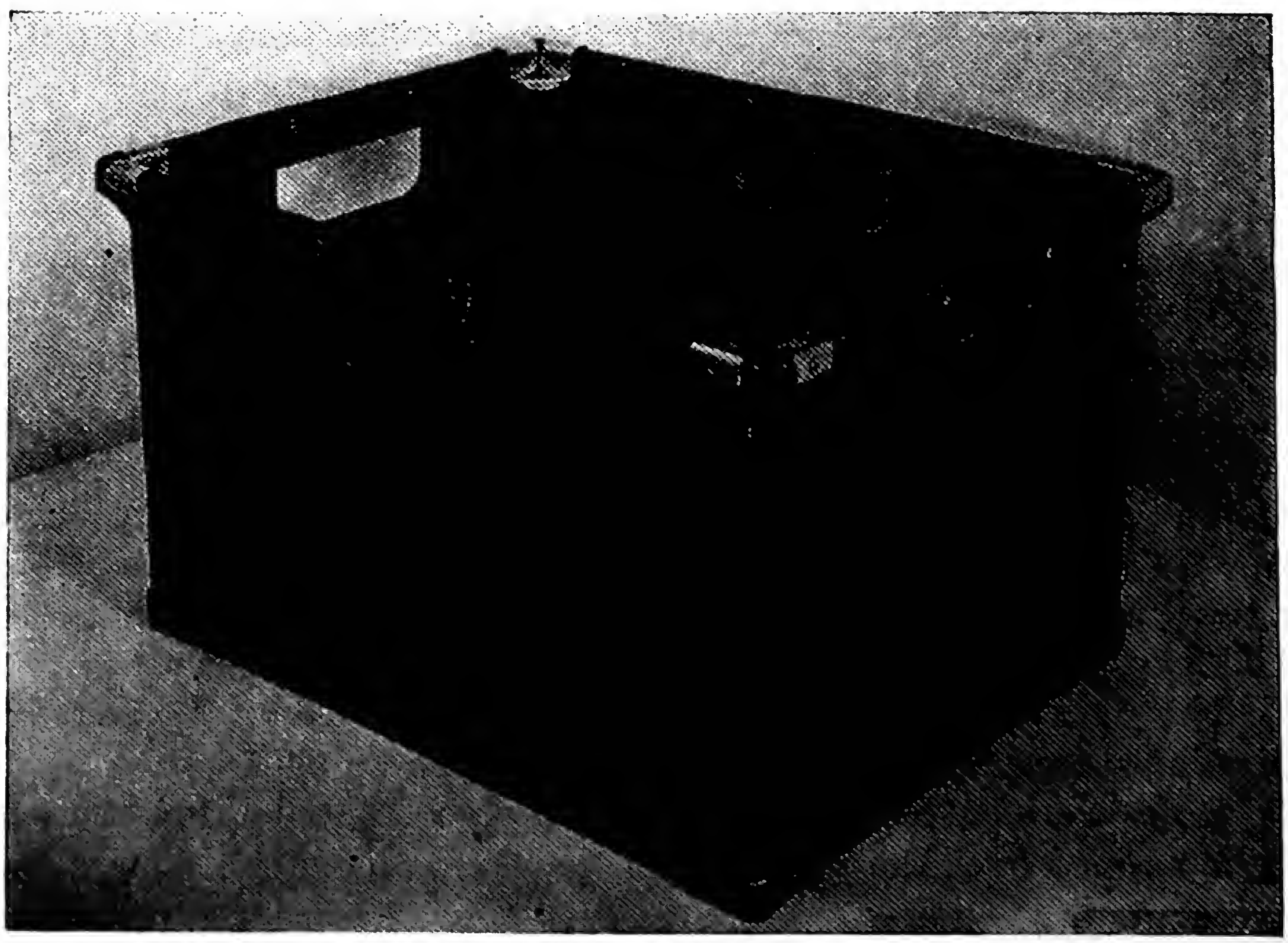


FIGURE 54. Completed milk bottle case made of reinforced plastics.

impregnated cloth. This width of cloth was just sufficient to cover the area between the top and bottom inserts. This wrap covered the edges of the first two layers of cloth which had been folded back over the top and bottom reinforcement rings. Also it covered the flanges on the ends of the longitudinal spacers and fingers on the spider attachments.

(8) The metal plate was placed on the top of the mold in the recesses provided for it.

(9) The plastic was covered with a layer of Cellophane.

(10) A formed vacuum sheet was placed over the plastic lay-up. This vacuum sheet was made of $\frac{1}{32}''$ rubber, tailored to fit snugly over the mold, and a flange on the cover sheet extended to the edge of the metal plate under the wood mold. Using "C" clamps and wood strips, the cover sheet was clamped to the metal plate with a vacuum-tight seal.

(11) A vacuum was drawn on the lay-up by means of a vacuum connection through the bottom metal plate.

(12) The assembly was cured in a hot-air oven on a cure cycle recommended by the manufacturer of the resin.

After-Operations:

(1) After removal from the mold four hand holes were cut as shown in Figure 54. Plastic handles, made over a wood male mold, were riveted to the upper reinforcing ring. Top view is shown in Figure 53.

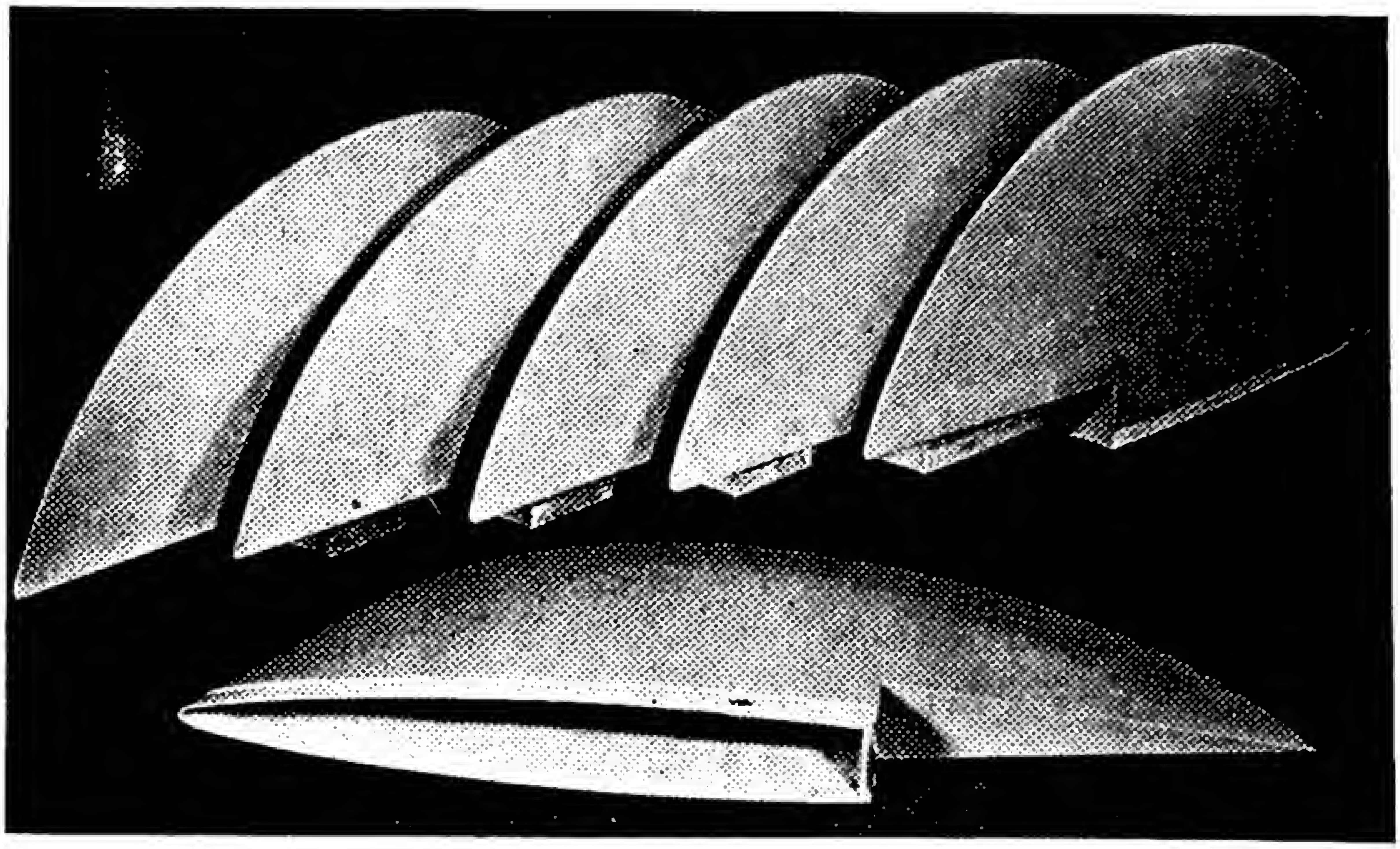
(2) Metal corners were riveted to the four corners, top and bottom. They are for sliding on concrete floors and for stacking.

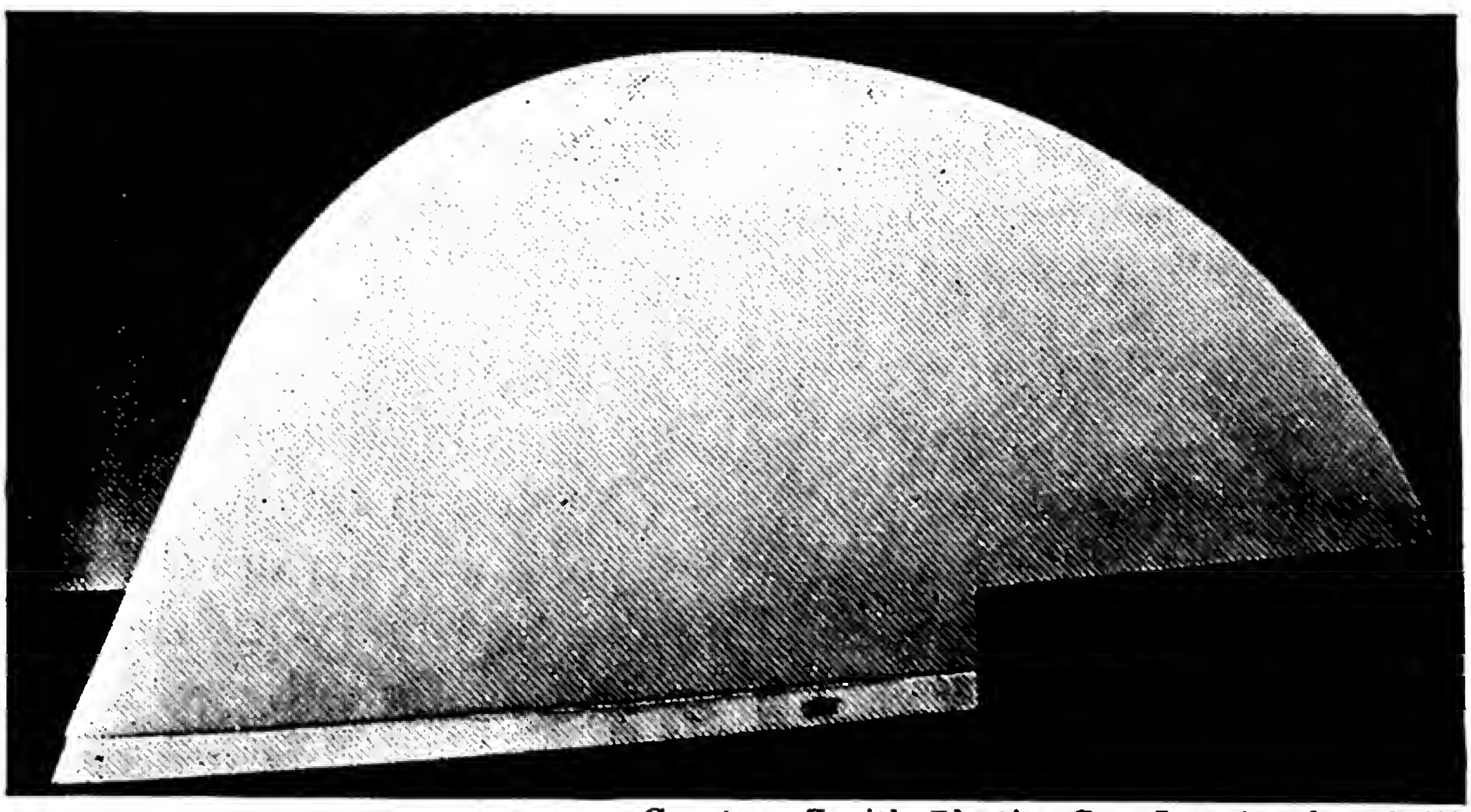
Looking toward improvement of laminating techniques, we shall present in the remainder of this chapter a few glimpses of suggested methods which may be adapted for production line operations.

Fundamentally, the high costs of hand lay-up operations must be reduced by practical means of mechanization. One such method is illustrated by the use of a "blowing" technique by which formed parts are shaped by an air flotation method. This process is well known in the manufacture of felt hats from rabbit fur, beaver and the like.

Bundles of glass fibers are laid parallel and rolled up in a piece of paper for convenience in handling. A refractory saw is used to cut them into the desired length, as shown in Figures 69 and 70. Such a refractory saw may be obtained from the

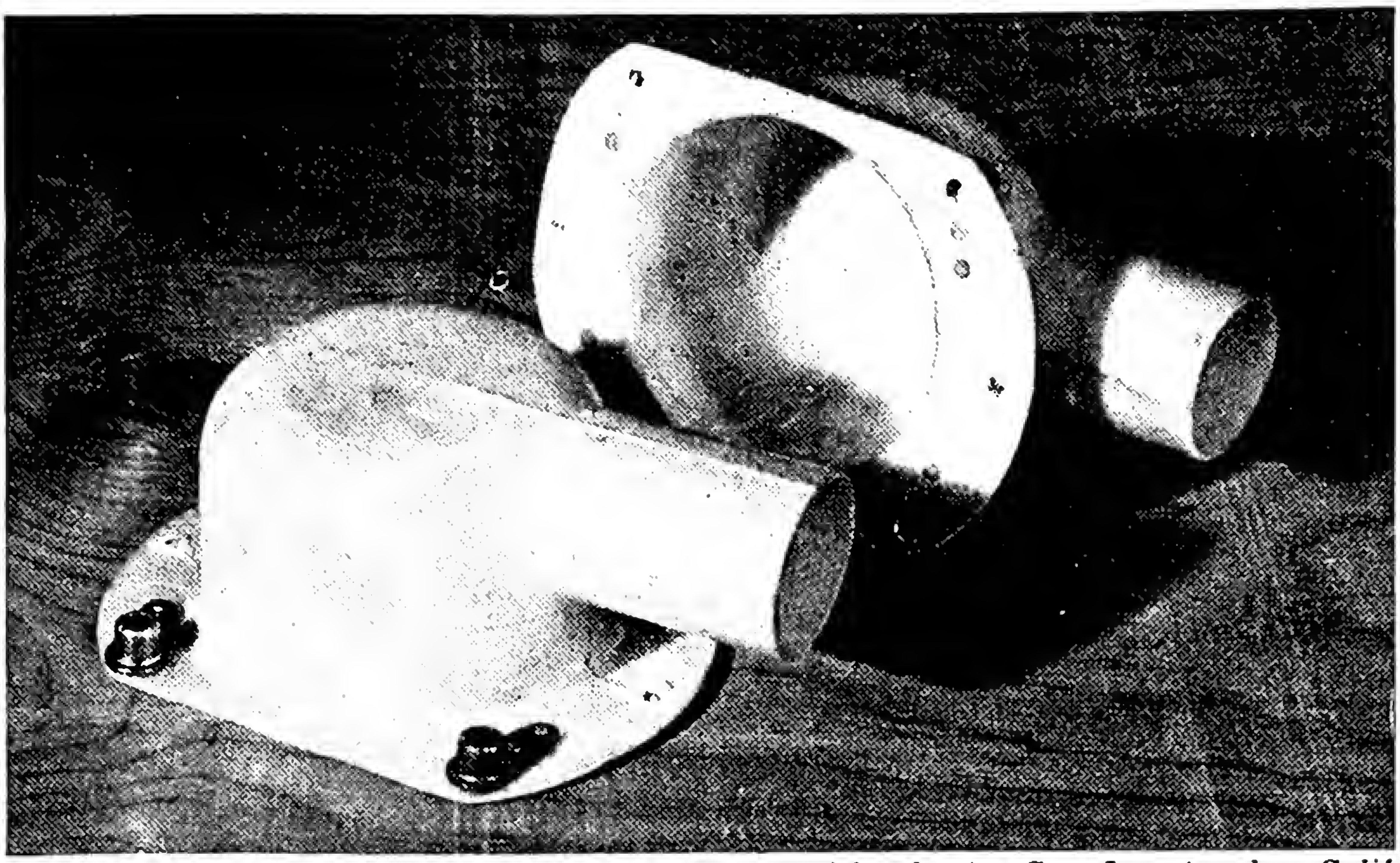
Clipper Manufacturing Co., 4030 Manchester Ave., St. Louis 10, Mo.





Courtesy Zenith Plastics Co., Los Angeles, Calif.

FIGURES 55 AND 56. A vertical fin, which contains the antenna of one of the fastest jet pursuit planes of the day. Structural stability, precision, and dielectric quality made it necessary to hold all dimensions within .006 inch tolerance. Construction is of Fiberglas cloth and thermosetting resin. It is a wet layup over a split male and a 2-piece female mold with reinforcement built up in stress areas. Such an external surface had to be free from pits and pores which would create drag on on the airplane.



Courtesy Zenith Plastics Co., Los Angeles, Calif.

FIGURE 57. This is a part of a cold air ducting system used in many passenger planes, as well as military planes. It is made of Fiberglas cloth, 2 plies and a thermo-setting resin. Note plates and holes for attachment; thickness of this part is .032 inch. Produced in thousand lots. They are made on a plaster breakout and a female aluminum mold.

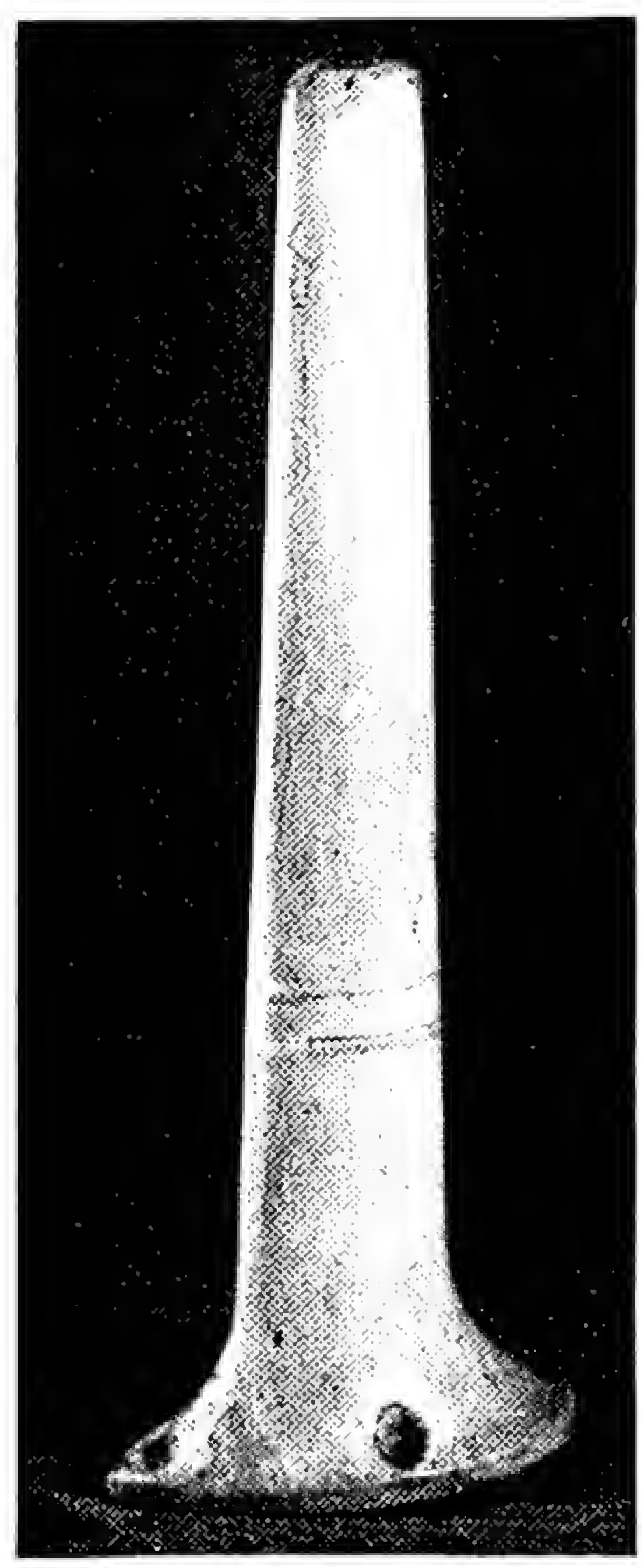
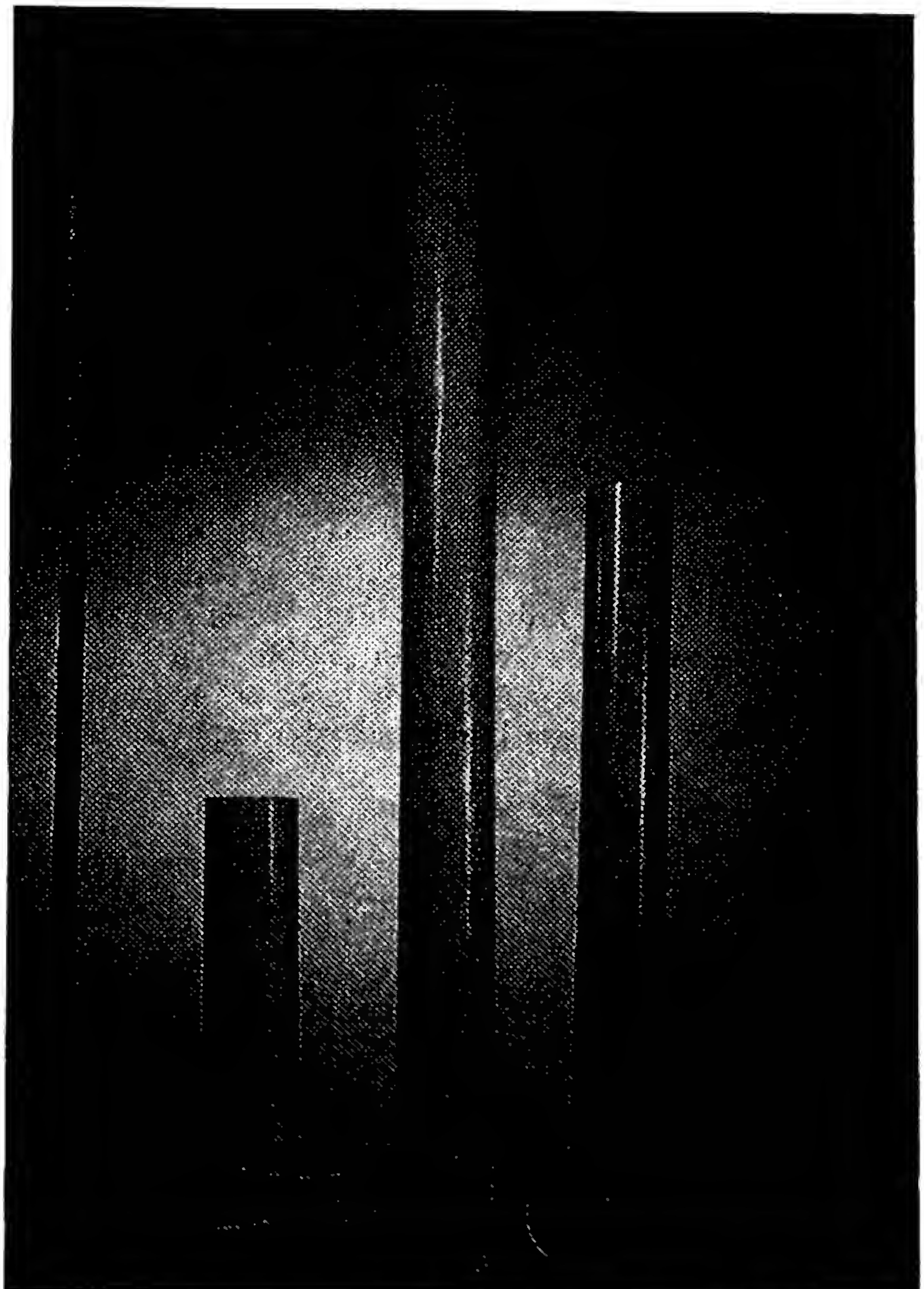


FIGURE 58.

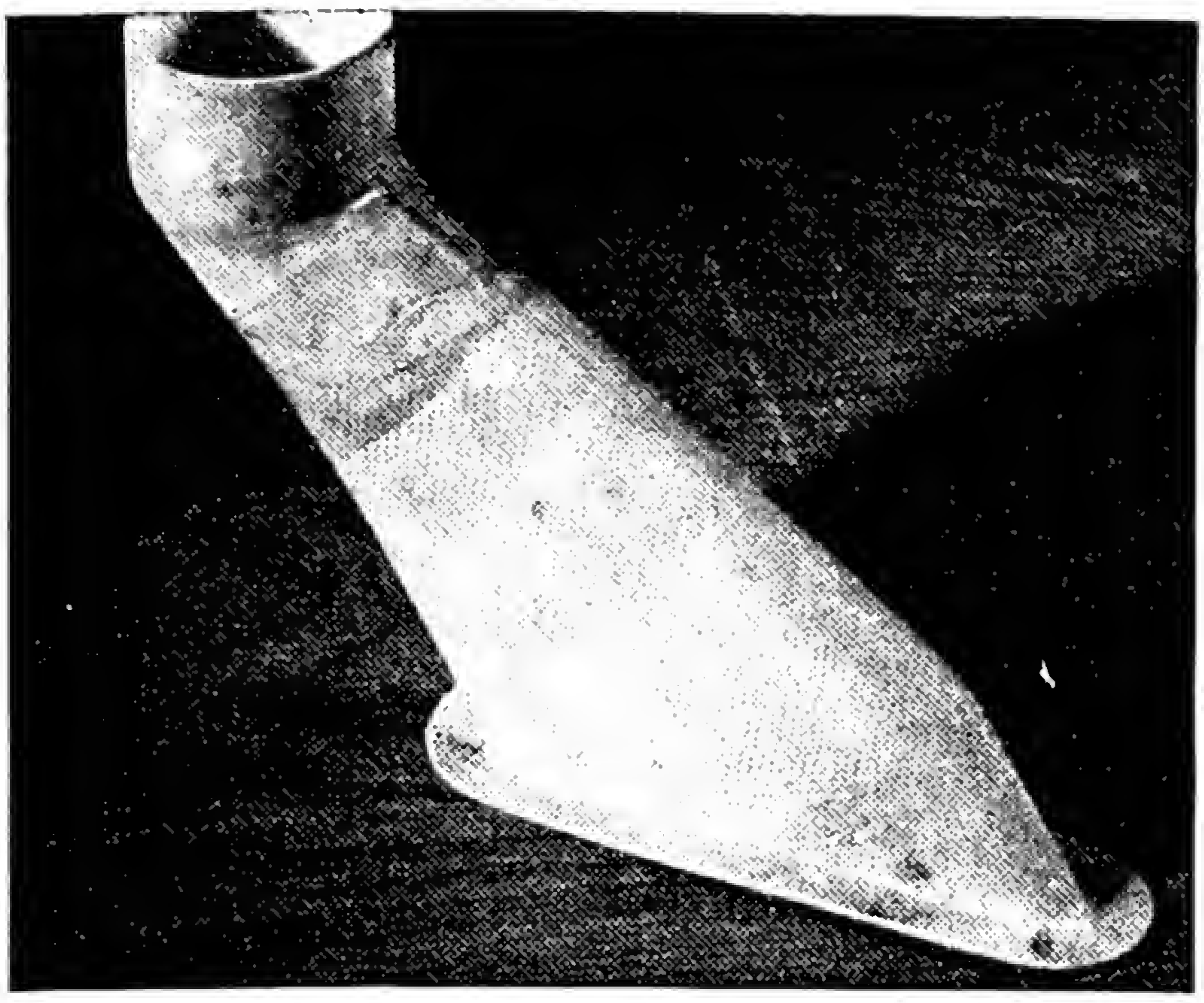
Antenna mast of which several shapes and lengths are required. Made in a male and female die. It has very high strength requirements, and since it is an external surface, it must be free from pits and pores. Thickness is varied, at the base it is $\frac{5}{32}$ inch tapering to $\frac{3}{32}$ inch at tip. Attachment holes are counterbored so that heads of screws may be faired.

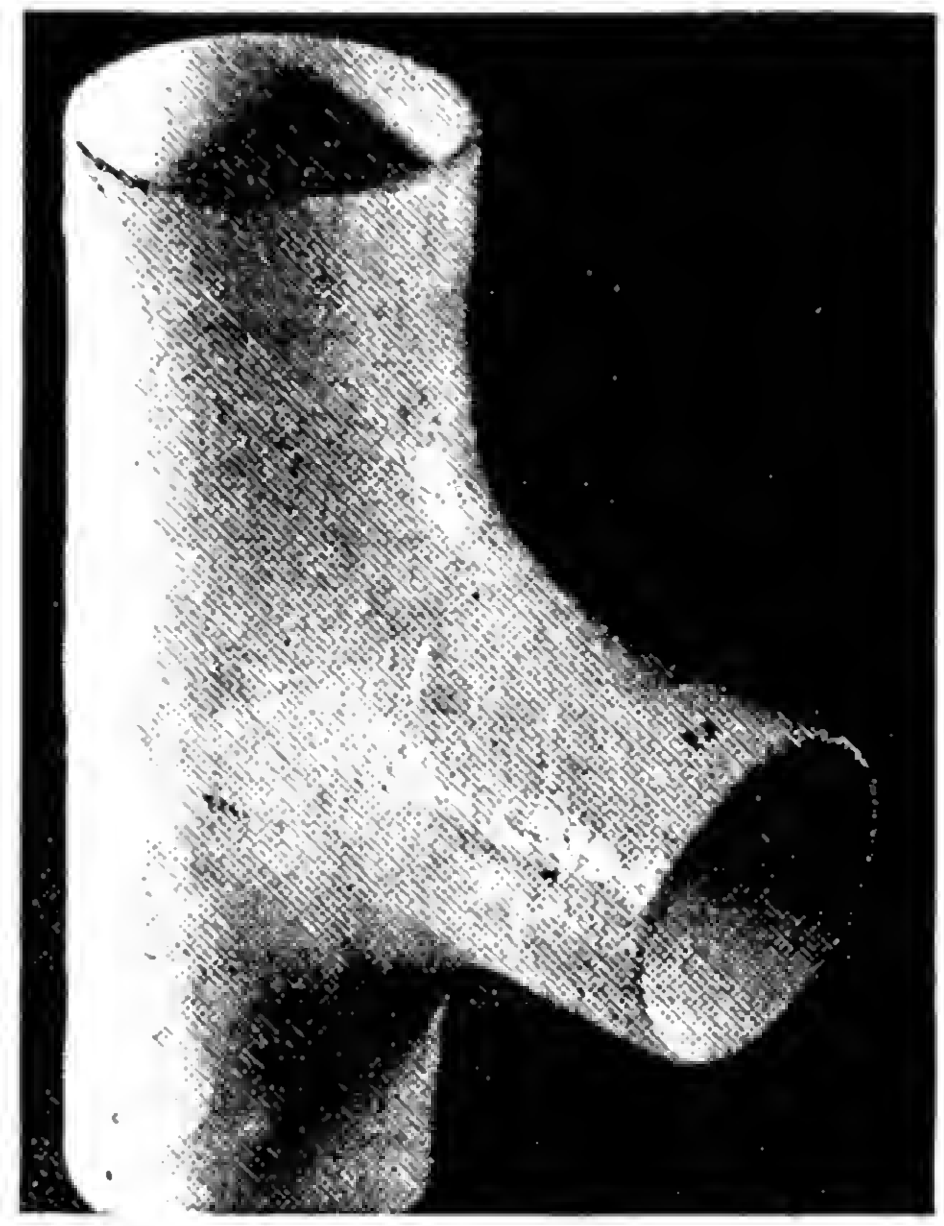
Courtesy Zenith Plastics Co., Los Angeles, Calif.

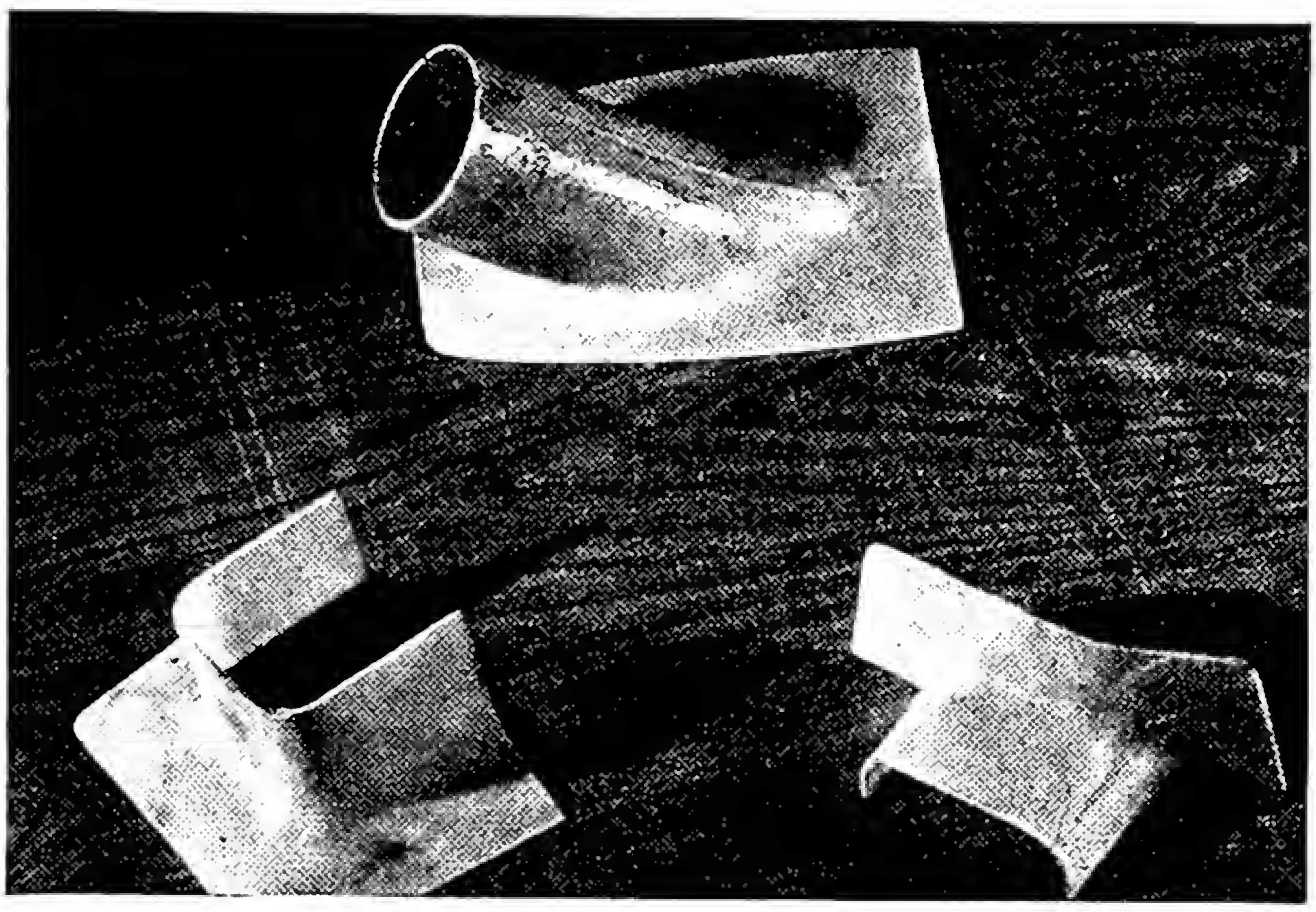


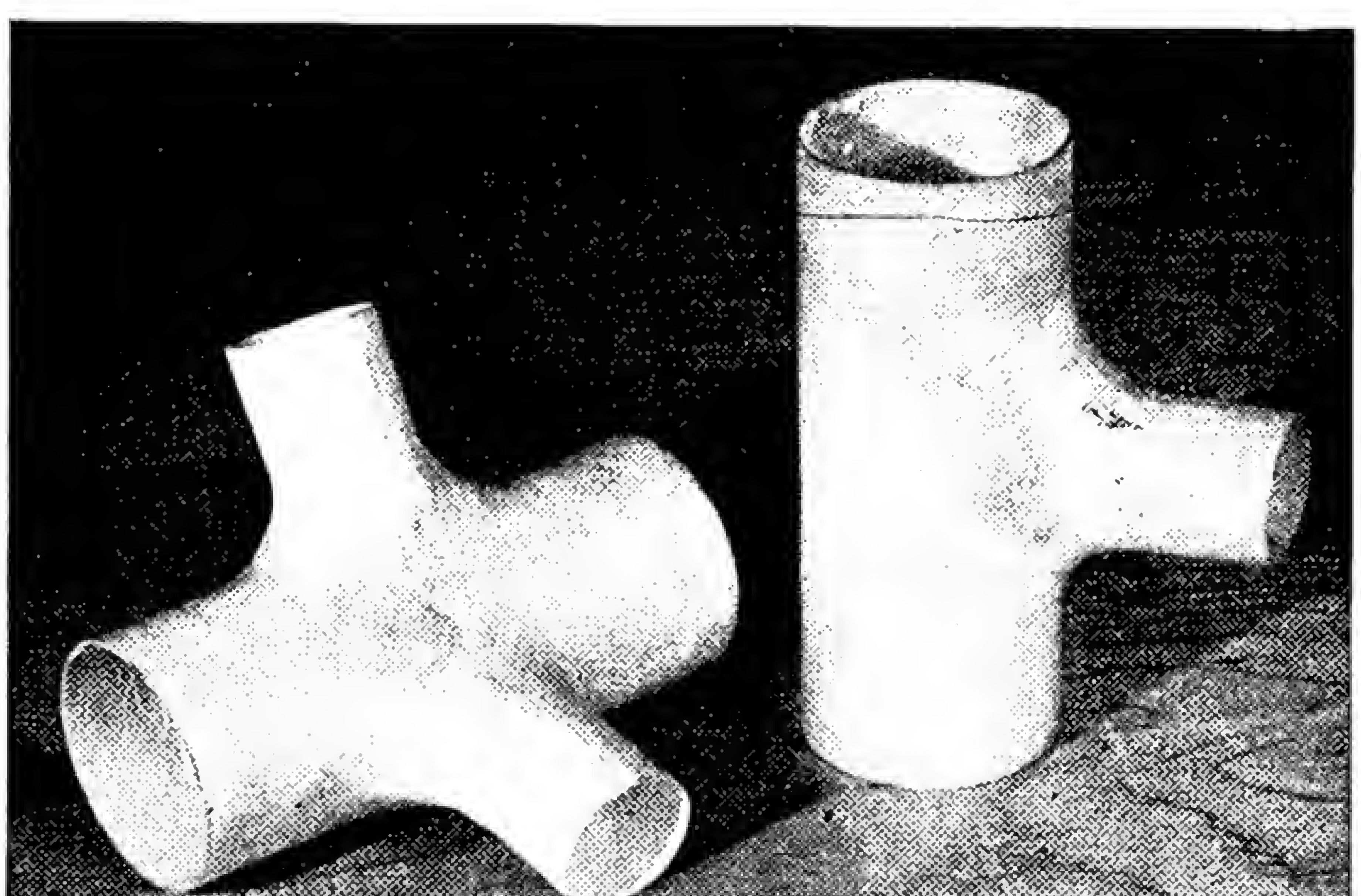
Courtesy Zenith Plastics Co., Los Angeles, Calif.

FIGURE 59. Several lengths of Fiberglas tubing used in the ventilating systems of passenger planes .032 inch wall thickness; 2½ inch diameter and in any length up to 38 inches, and any diameter which might be needed. This is manufactured by the metal mandrel system. Larger tubing of this type is being developed for the petroleum pipe and chemical fields where corrosion, light weight and portability are involved. *(See Figures 60-63.)*









Courtesy Zenith Plastics Co., Los Angeles, Calif.

FIGURES 60-63. Elbows, tees and crosses of varied lengths and shapes can be made by a plaster breakout and wrapped, as shown. (*See Figure 59.*)

Courtesy Zenith Plastics Co., Los Angeles, Calif.

FIGURE 64, 65. Nose of a fast jet plane. This must be able to carry enough electricity to remove static from the nose and conduct it to the metal structure of the plane, thus grounding it; special treatment colors it black. It is $\frac{1}{8}$ inch in thickness and is made by a wet layup on a male and female die.

FIGURE 66.

Nose of latest passenger planes with landing light cover of lucite. Constructed of cloth, mat, and a thermo-setting resin. Size: 42 inches in diameter, 0.120 inch thick except in reinforced area around lucite window, which is $\frac{3}{8}$ inch. This is a wet layup on a male and female mold. (*See Note 1, p. 118.*)

Courtesy Zenith Plastics Co., Los Angeles, Calif.

FIGURE 67.

100-gallon water tank made from a thermo-setting resin, Fiberglas cloth, and kraft paper. It weighs only 55 lbs. Thickness 0.064 inch; all laminated plastic except fittings and studs; constructed with 4 baffles to prevent water surge. Tested with water at 212° F and 20 psi. Designed by Zenith Plastics Company for aircraft use. *(See Note 2, page 118.)*

Courtesy Zenith Plastics Co., Los Angeles, Calif.

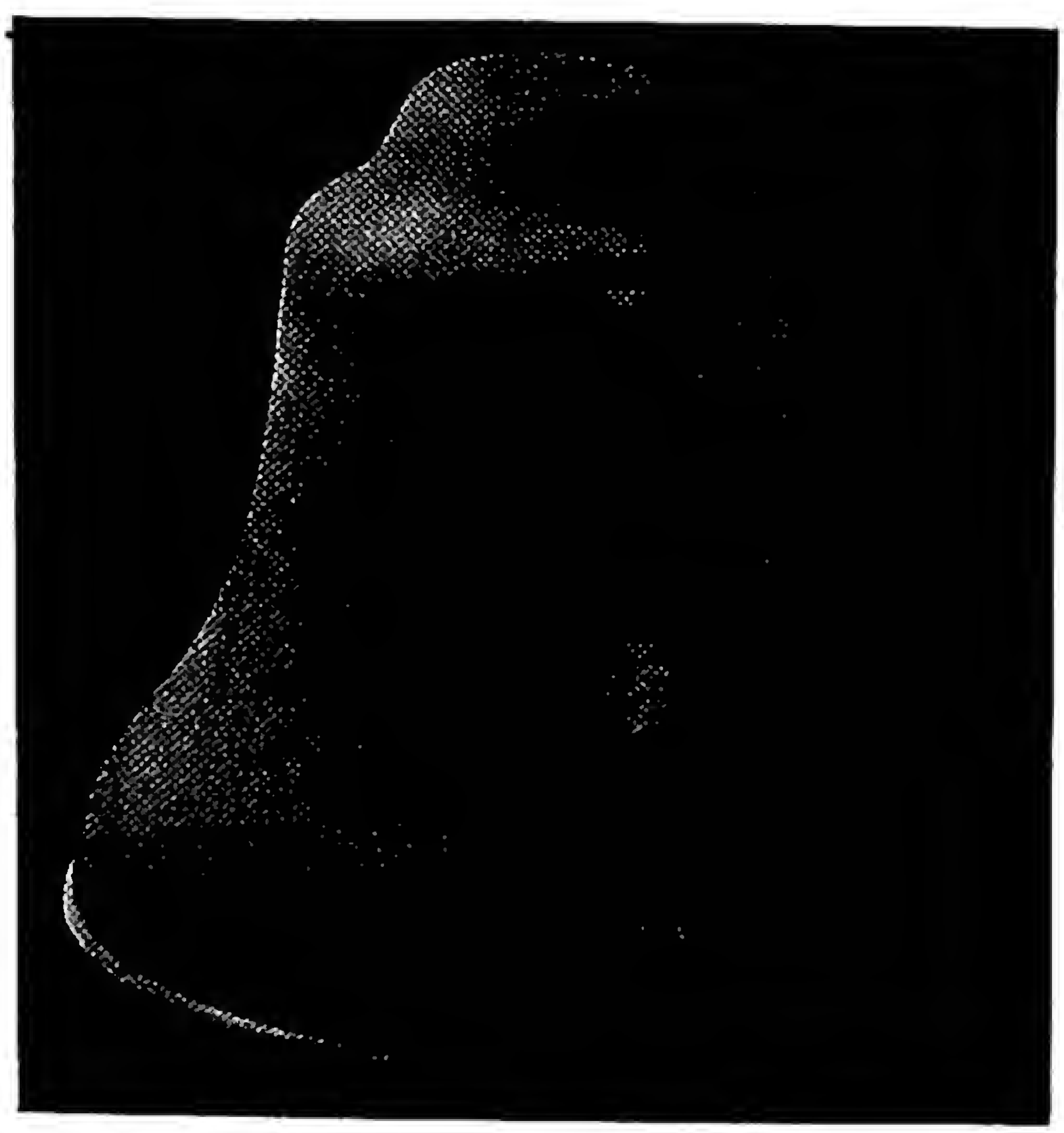


FIGURE 68.

A Christmas bell, molded by use of two metal dies. Glass mat was used in the single step operation of forming and curing. Various sizes can be made. Used for street decorations after a light application of paint or lacquer. *(See Note 3, p. 118.)*

Courtesy Industrial Plastics Co., Gardena, Claif.

Note 1. It was originally designed for formed phenolic when this was proven impracticable. Zenith Plastics Company then redesigned the tooling and made the part at a reduced cost in piece price and a tremendous reduction in tooling costs.

Note 2. Experiments were started on a 2-gallon tank with same temperature and pressure. Upon its completion an 8-gallon, then a 60-gallon, and finally the 100-gallon tank was constructed. Dimensions of tanks are as follows:

2 gal.	17″ long	x	6½″	diameter
8 gal.	32″ long	x	9″	diameter
60 gal.	70″ long	x	18″	diameter
100 gal.	100″ long	x	18″	diameter

Note 3. *Reference:* Mat Molding: "Applications of Low-Pressure Materials to the Compression Field," in *Pacific Plastics Magazine* for October 1946, pages 13-15. Details are illustrated and described for molding the Christmas bell. (Also see page 28 in the same magazine for a story on a low-pressure molded Fiberglas mat reinforced plastic miniature piano. The need for a sounding board is eliminated because the case acts as a diaphragm to impart resonance and tonal quality.)

Note 4. Small quantities may be cut with a paper cutter or shears. For cutting larger quantities, it is suggested that a set of high speed gang refractory saws, spaced as needed, be used in conjunction with a conveyor.

FIGURE 69. A clipper refractory saw cutting a bundle of glass fibers or rather a hank of Fiberglas yarn, which is wrapped with paper to facilitate handling. (*See Note 4, p. 118.*)

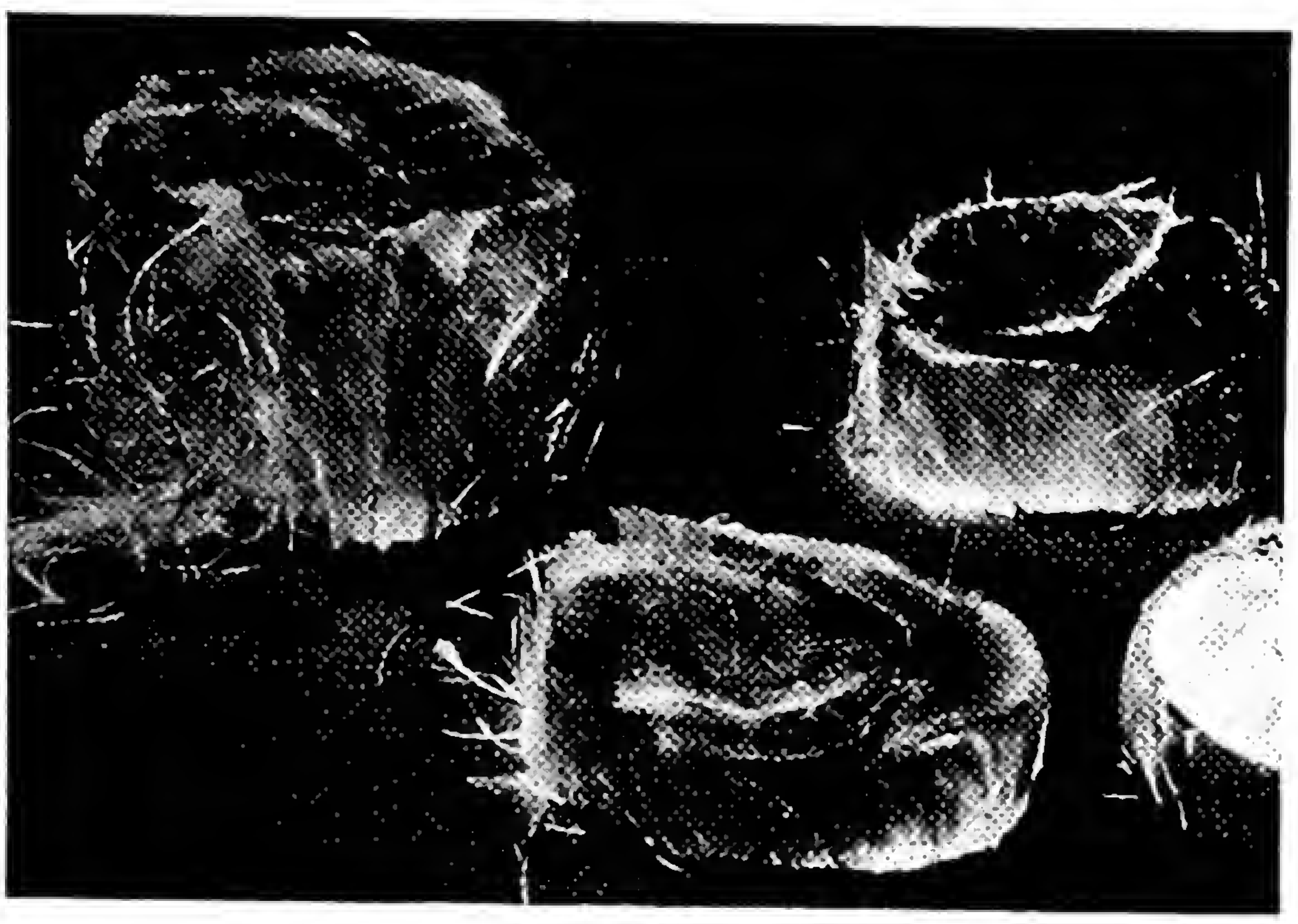


FIGURE 70.
Fiberglas 150's fibers cut by the refractory saw shown in Figure 69.

FIGURE 71. A transparent plastic chamber used to fluff bundles of glass fibers shown in Figure 70.

The dense bundles of glass fibers must be "fluffed" or dispersed. This can be done in a chamber, as shown in Figure 71. Compressed air jets accomplish this dispersion quite readily.

Two forms of experimental machines for blowing the loose fibers for deposition on suitable screen forms are shown in Figures 72 and 73. Both are experimental chambers designed for use of blowers, compressed air and vacuum supply as required. It is desirable to include adequate dampers and the like in order to control or modify the volume of air, the direction, and velocity of its flow, and to provide for "gusts" or "blasts" of air occasionally within the chamber. Thus controlled conditions could be established for the formation of a uniform product, for subsequent incorporation in the curing step with resin.

In the operations of these machines the flotation is accomplished so that fibers move upward to be deposited on wire screen forms as shown in Figures 74 and 75. These screens may be placed with concave or convex face exposed to fiber forming. Down-draft movement of fibers to a screen might also be accomplished.

One convenient method for the transfer of such fibers to a mold for curing is to use a thermoplastic sheet liner suitably shaped for the formed part.

The felted fiber form may be tapped gently onto the plastic liner sheet, the sheet placed in the female mold, catalyzed resin added, the male mold liner placed thereon, then the male mold set in place and clamps applied, as shown in Figure 76.

The cast aluminum mold shown produces a reinforced plastic dome, as shown in Figure 77. This shape is often seen on street lighting globes.

When the fibers are formed on the screen, a light spray of resin or other suitable binder can be applied to hold the fibers in place. Thus transfer of the form could be accomplished without the use of thermoplastic sheet liners.

It should be mentioned that the porosity in the aluminum castings used for curing the lamp globe form shown in Figure 77 necessitated the use of a thermoplastic sheet liner for quick parting. The usual mold release agents or parting compounds described in Chapter 2 were not so effective on such a mold. A stainless steel mold with a smooth surface requires no such thermoplastic sheet liner for easy parting of the laminate from the mold.

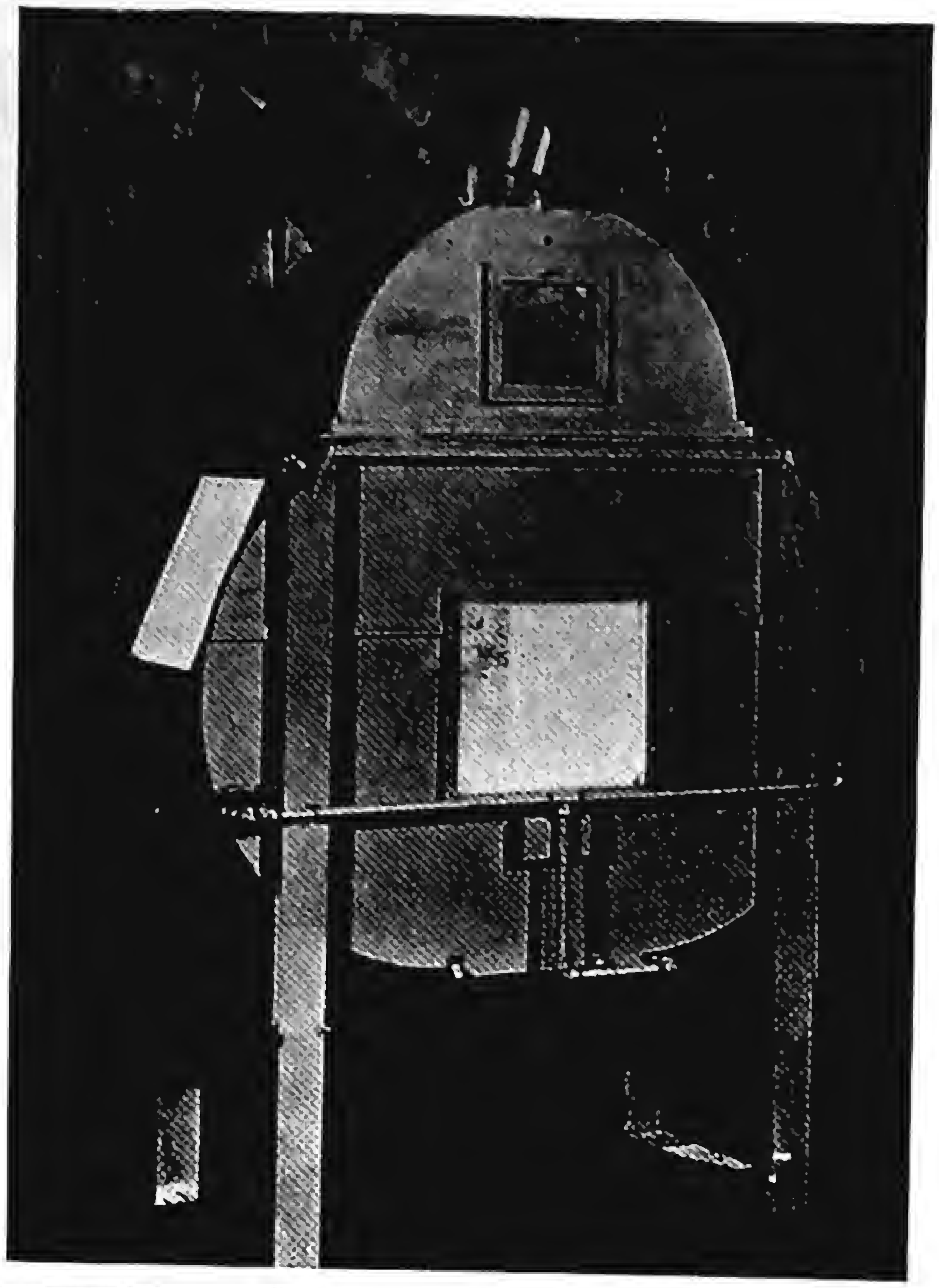


FIGURE 72.

An early experimental form of fiber thrower used to make preforms by suction and a felting action. Screen forms were inserted in the upper part of this device.

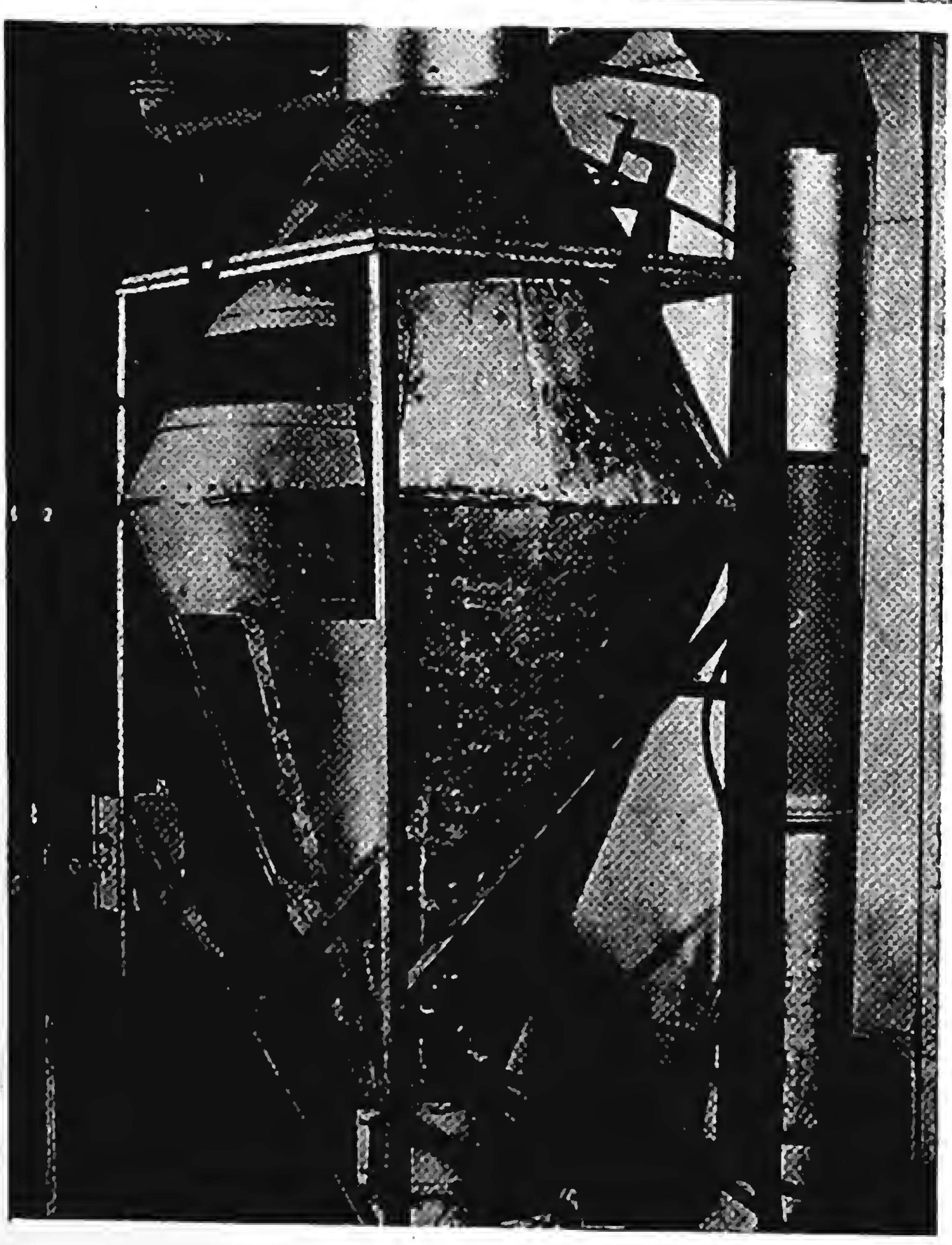


FIGURE 73.

A later experimental form of fiber thrower of "cyclone" shape or design. New machines make use of picker rolls for the uniform distribution of glass fibers before they reach the air chamber containing the forming screen.

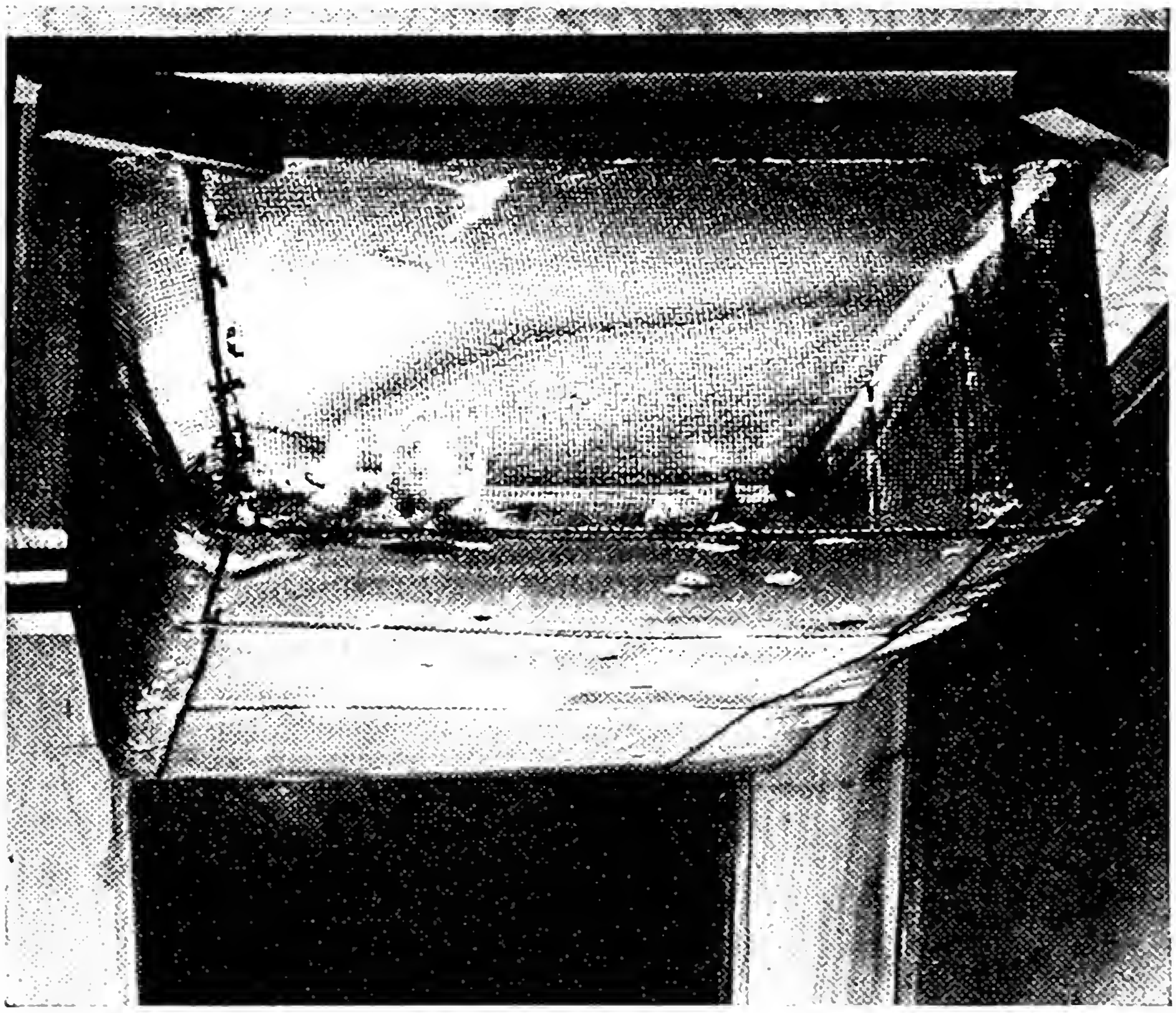


FIGURE 74. A rectangular shaped screen for fiber preform of half of a piece of luggage.

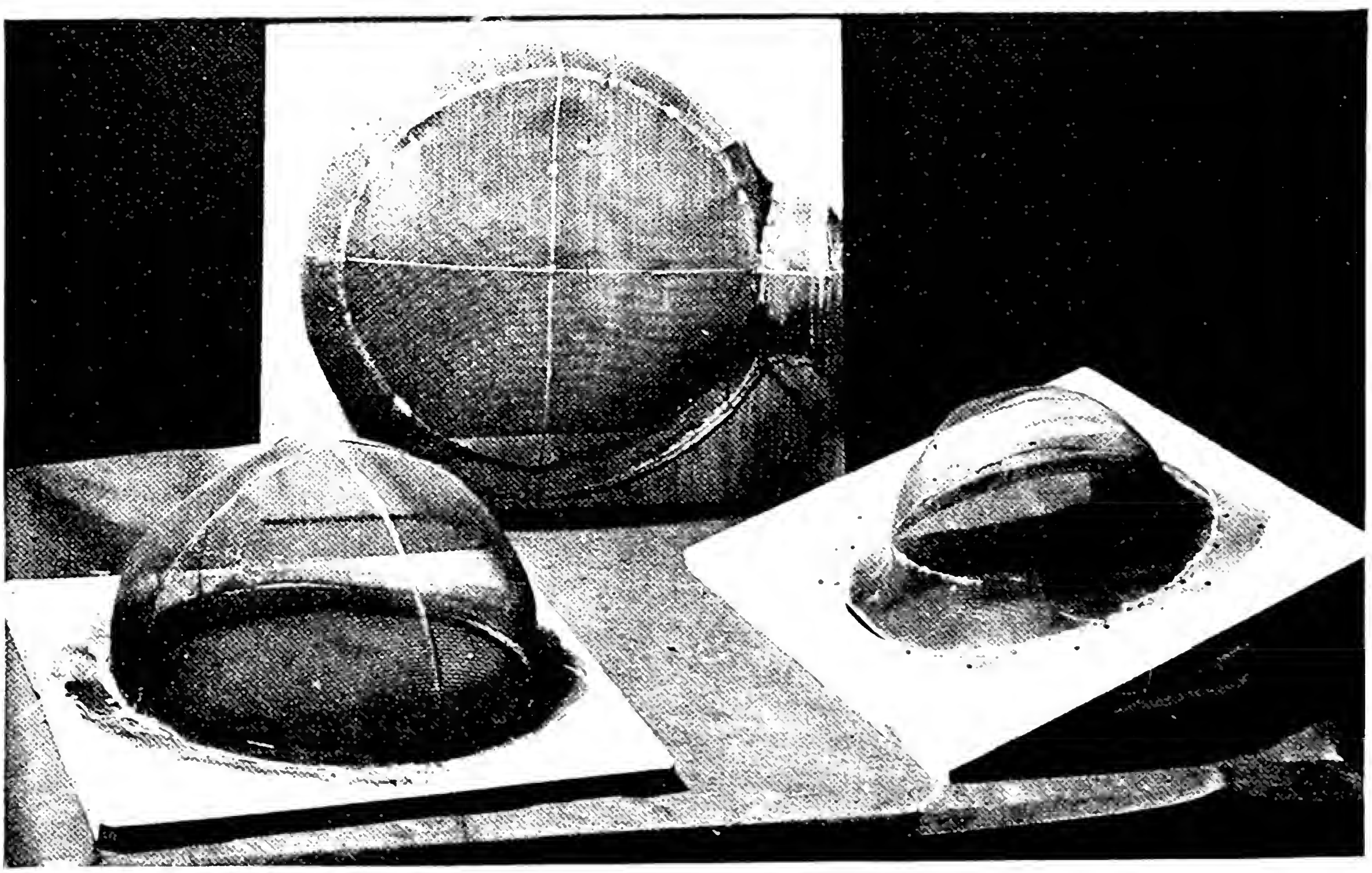


FIGURE 75. Screens for use in making preforms. *Left to right:* Street lamp globe, half of a gasoline filling station pump light globe, and a safety helmet.

FIGURE 76. Two cast aluminum molds, both male and female parts. On the left, is the safety helmet; on the right is the street lamp globe mold.

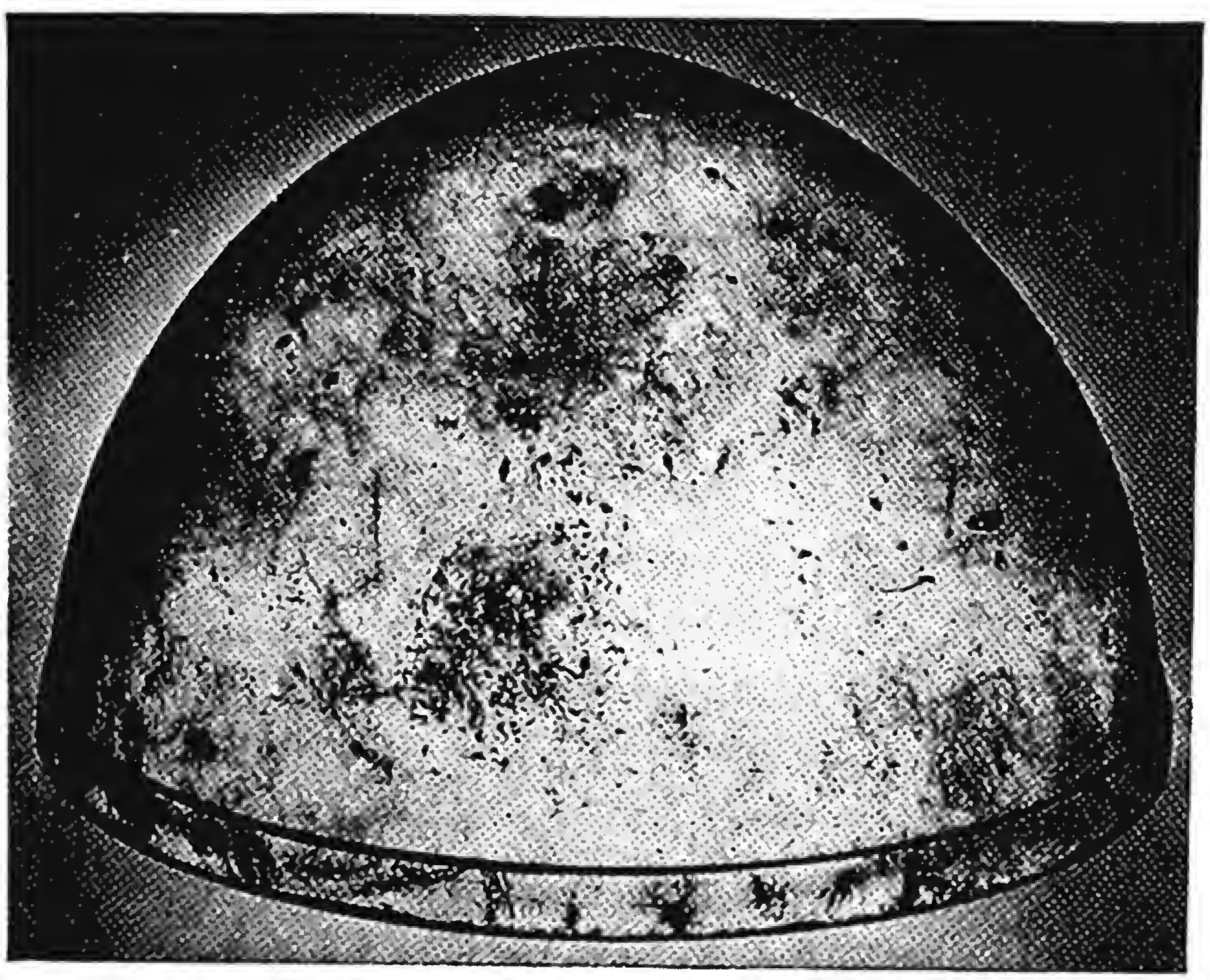


FIGURE 77. Reinforced plastic street lamp globe, made experimentally from blown fibers in the machine (Figure 72) and molded in the dies shown in Figure 76.

Another system of handling fibers of glass is to pass the fluffy material in mat form through a picker. Powdered resin, of either the thermoplastic or thermosetting type, may be added prior to passage through the picker. The quantity added may be small if it is to serve as a binder, or large enough to be a complete moldable mixture. As the mat and resin pass into the aeration or blowing chamber in a disintegrated form, the suction through the wire screen form quickly draws the mixture on to the form in a uniform felted layer. Slight heating is usually enough to bond the fibers and resin so that transfer to molds is easily accomplished.

Hat making machines now make over 3,000 dozen per day with highly mechanized equipment which is adaptable to use for making Fiberglas preforms in the reinforced plastics field. Experimental work is proceeding along such developmental lines.

Another method suitable for use on the production line for laminating plastics is the *rubber plunger technique.* This has been shown schematically in Figures 28 and 29 (p. 54, 56). In the latter illustration a slip ring is used. With such a method the reinforcing material may be pre-cut to a suitable pattern if it cannot be drawn or shaped to the contour of the mold from flat sheet stock.

Figure 78 shows a stainless steel female mold for a box approximately 7″ square and 3″ deep. The rubber plunger is shown attached to the ram which supplies pressure prior to and during the curing cycle. The mold is attached to lines to supply steam for heating as well as water for cooling.

The rubber plunger shown is of solid rubber, made from uncured sheet, which is cut to size and shape desired, and then cured. A combination rubber plug with a hollow core filled with liquid would give advantages not attainable by the rubber plug alone. Uniform pressure would then be assured to all portions of the mold face. Thermoplastic resins plus a reinforcing layer of glass mat may be formed or "drawn" as readily as thermosetting resins.

In the thermoplastic field styrene is the leader in volume usage. Expanded facilities by one producer will give that company eleven times the prewar world production. It has been predicted that the 1947 rate of production of styrene plastic in the United States and Canada will exceed 150,000,000 pounds a year.

Styrene was $0.72 per pound in 1939 and is now $0.25 per pound. It may be modified to give an unlimited variety of color effects. It

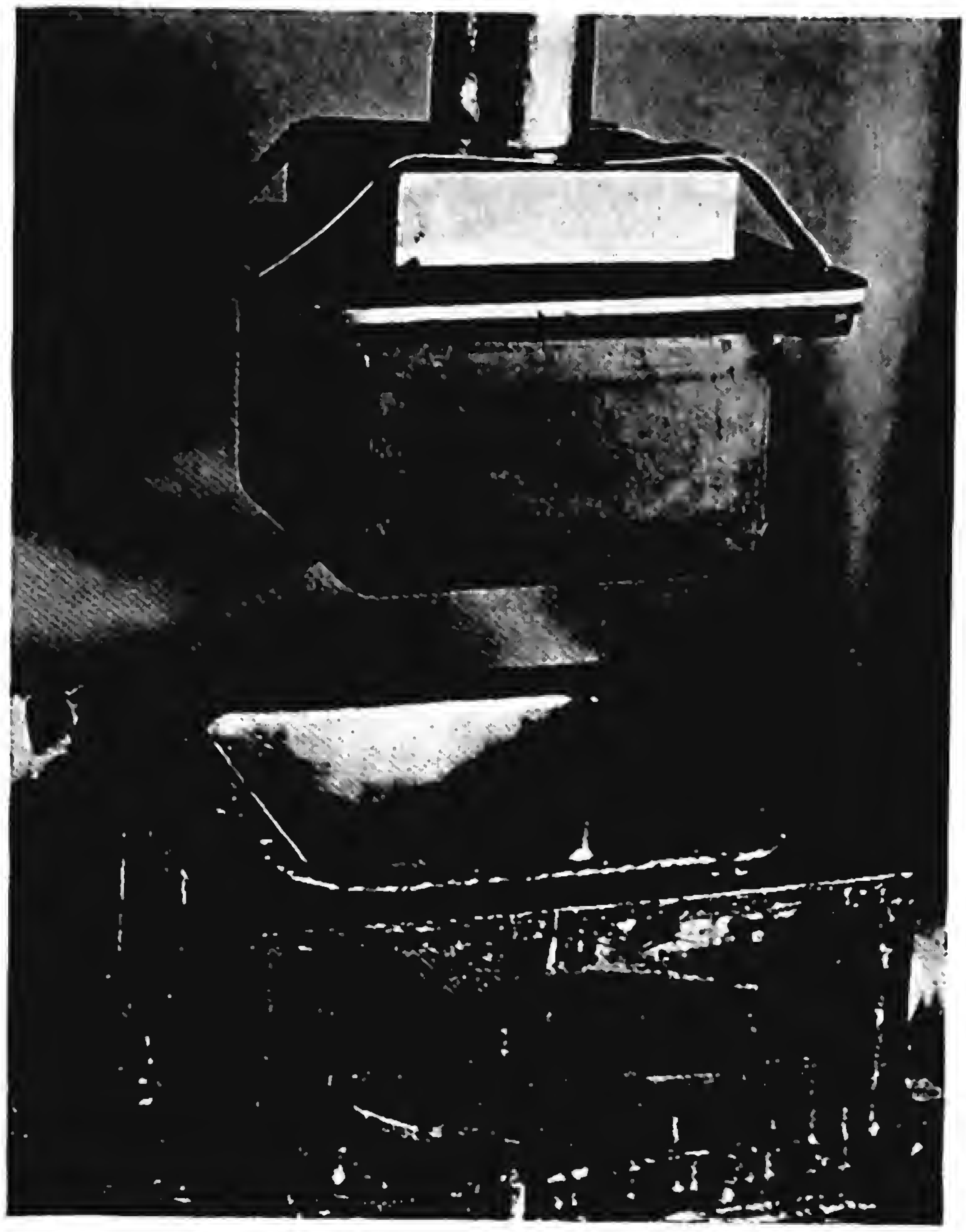


FIGURE 78.

Rubber plug and stainless steel lined mold. A hydraulic cylinder applies the force to the rubber plug for molding at pressures of 20 to 100 psi.

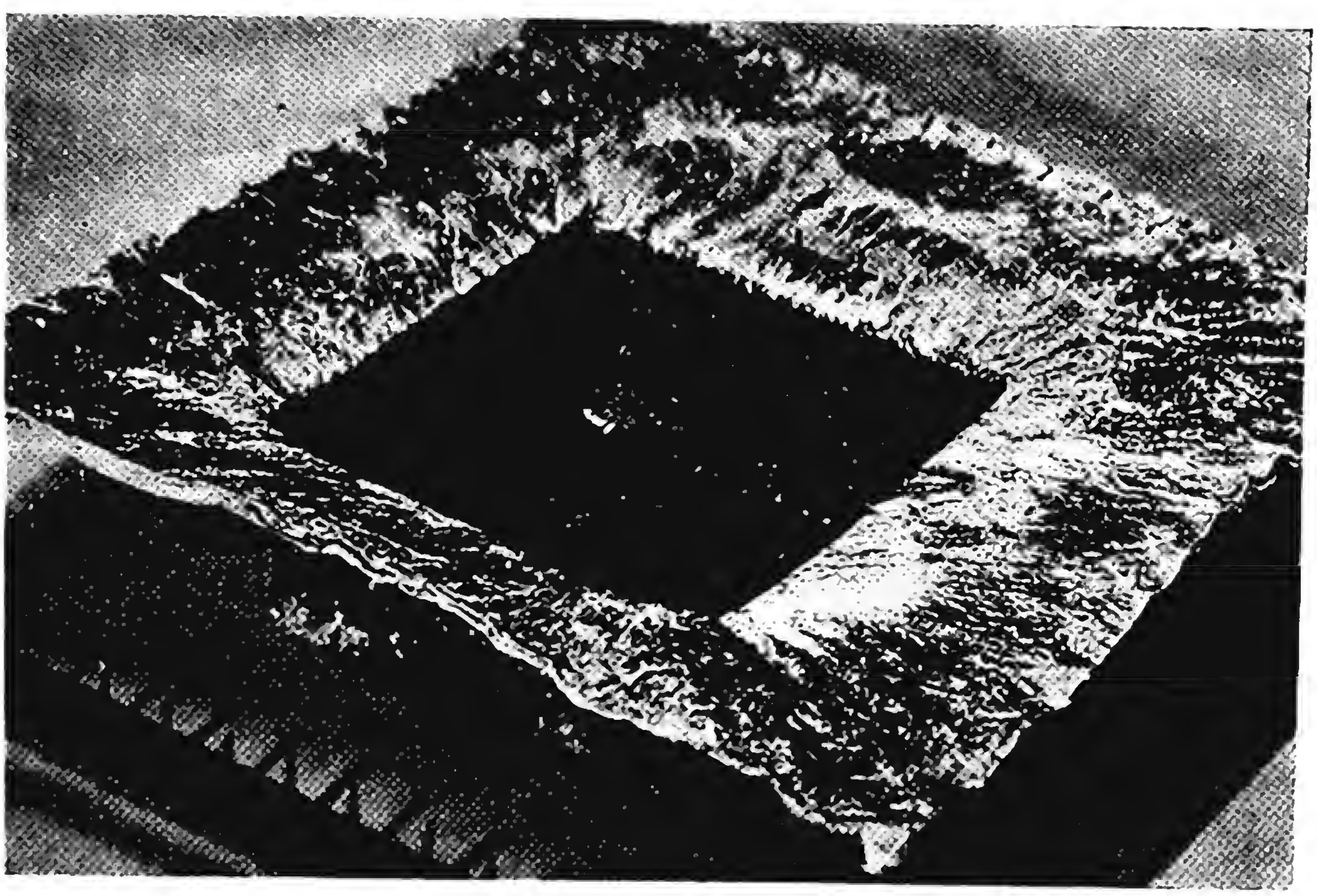


FIGURE 79. Box preform made on the mold shown in Figure 78. Glass mat T-35K was used. The operation resembles the drawing of a soft metal or a thermo-plastic sheet.

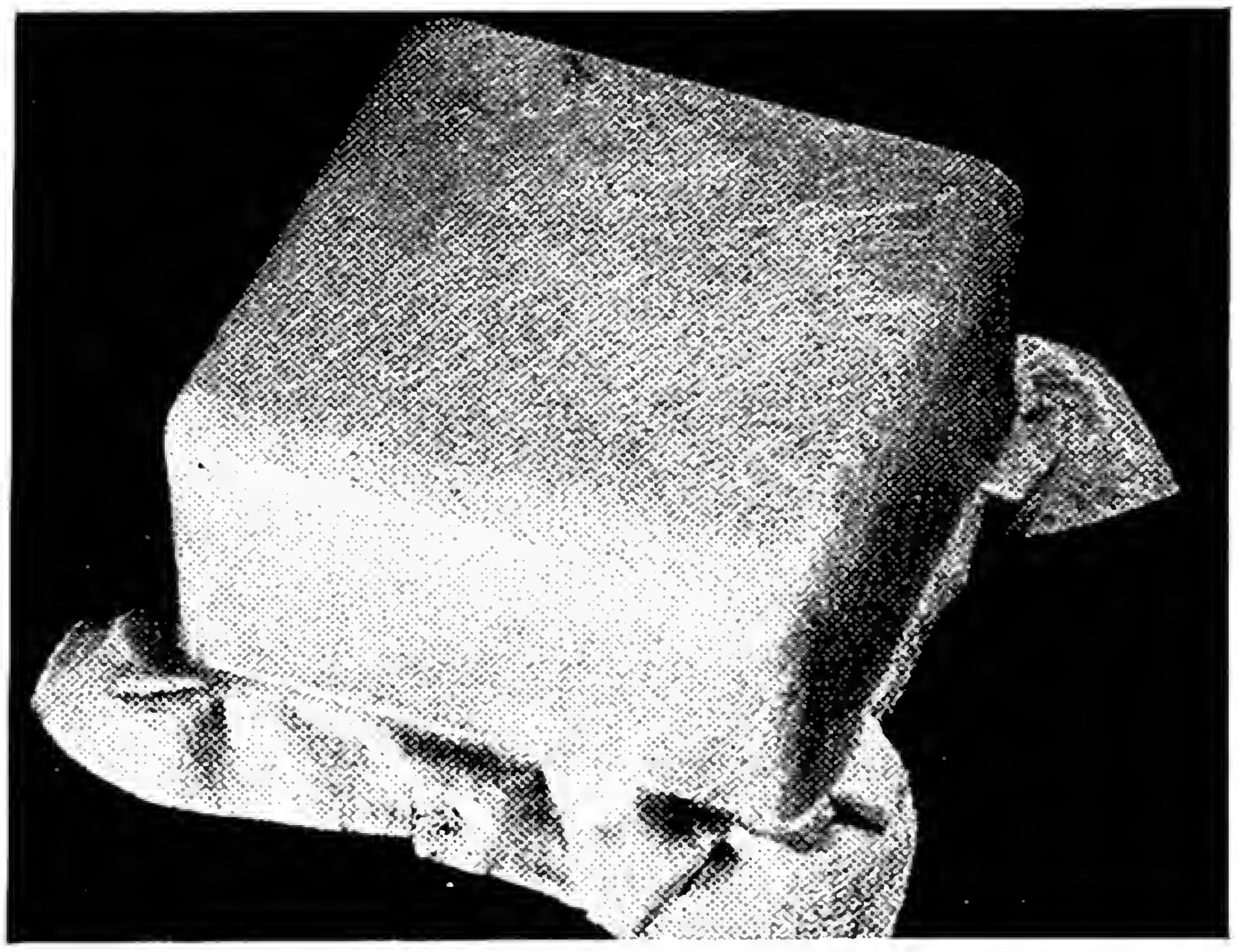


FIGURE 80.
A box formed from glass mat T-35K and Loabond, a styrene laminating resin.

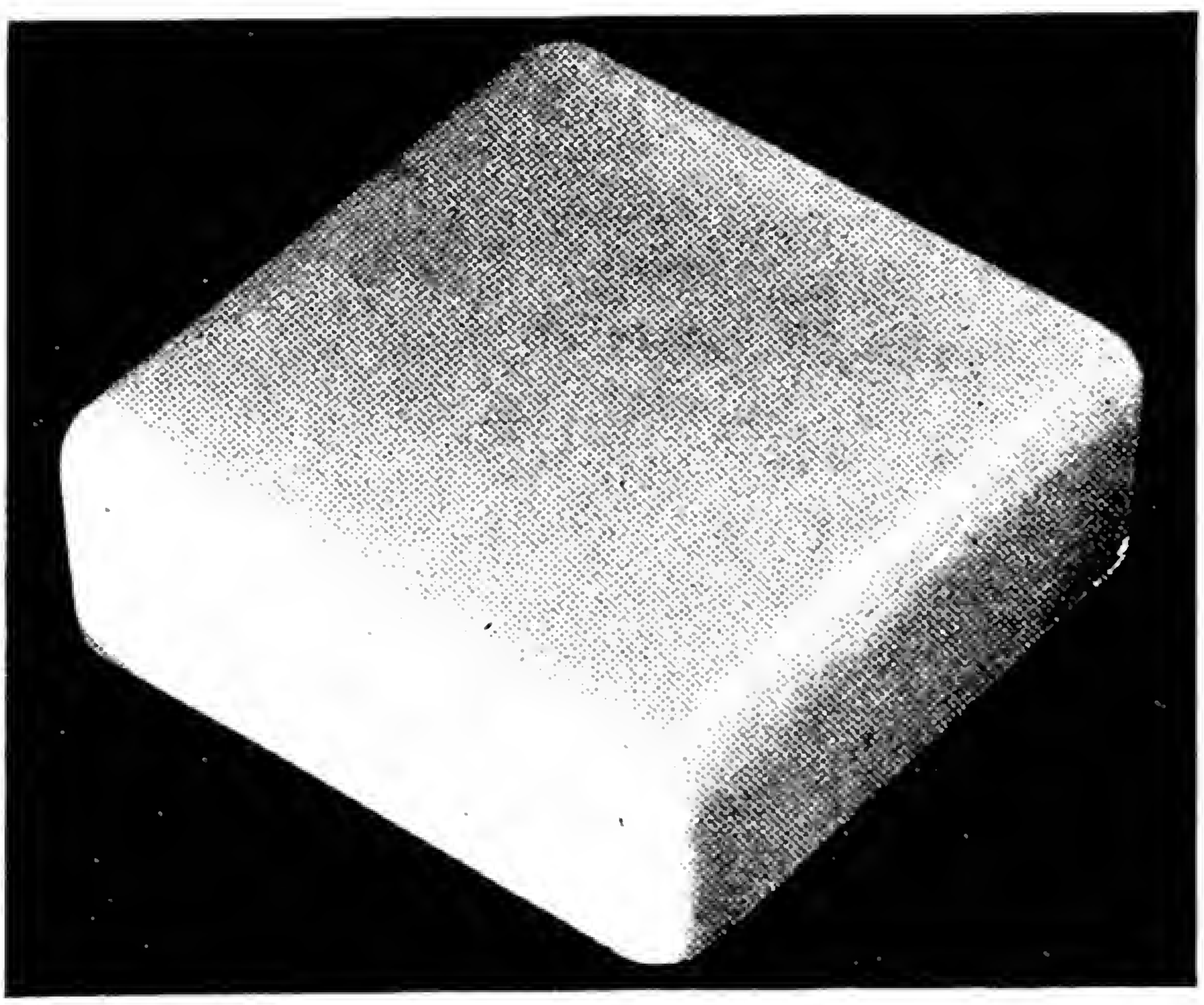


FIGURE 81.
The rough laminated box has been trimmed.

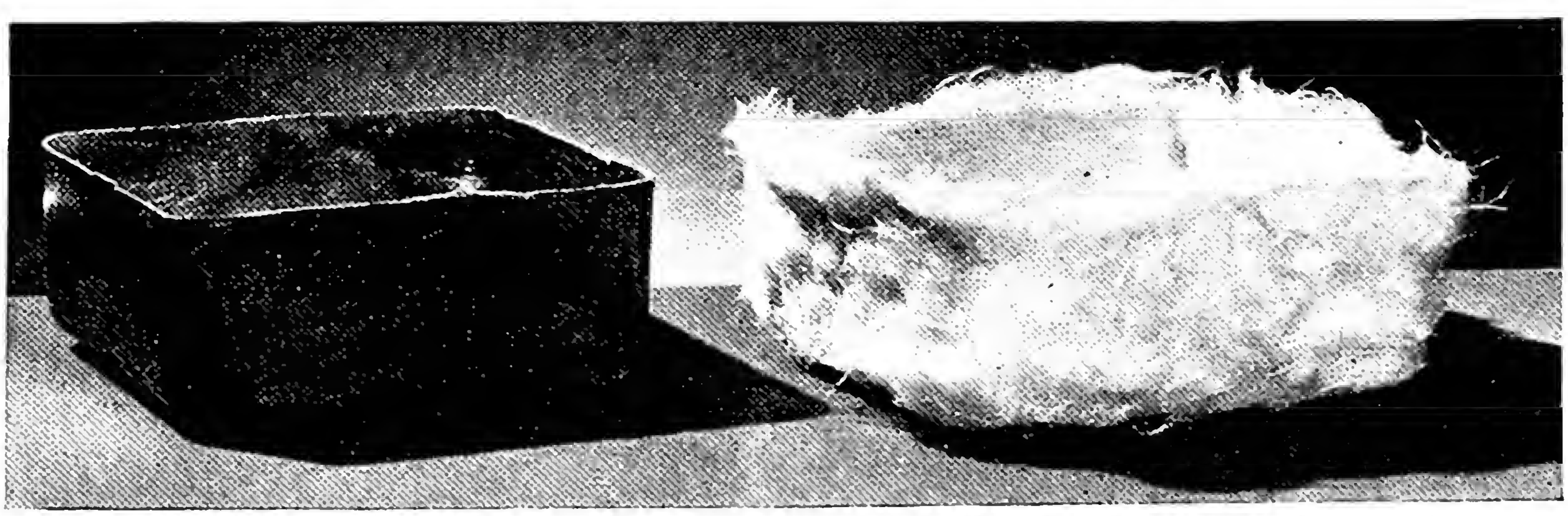


FIGURE 82. Formed glass fiber box made by the blowing process. The box was molded by the plunger process. (*See pages 124 and 125.*)

has excellent resistance to acids, alkalies and many solvents, as well as unusual dimensional stability. It has been said that styrene and its meritorious qualities bear the same low cost relationship to thermoplastic resins as phenolics bear to the field of thermosetting resins.

The laminator may design his own production line for the manufacture of reinforced plastics. Suitable materials for his product flow in from the supplier—both resins and reinforcing materials.

Facilities are provided for mixing the catalyst with the resin and for applying the resin to cloth or mat in continuous flat sheet form. Some resins require no catalyst. In some operations it may be preferable to add the resin to the preform in the mold.

In the molding phase of the production line, a variety of combinations are available. The following types of mold may be used: a single mold with a rubber blanket or bag; two metal molds, one of which is actuated by a hydraulic ram; or one metal mold with a rubber plunger. Cost studies and production needs should be analyzed to arrive at the best method.

Metal inserts may be molded directly into the piece. Use of twin female molds will permit the lay-up of one laminate assembly while another is curing. Automatic timing of all phases of the molding cycle will reduce the operator's task to the simple gesture of pushing the starting button. Preheating the charge of resin reduces the time required in the press so that good production line techniques may be realized.

The cycle of time in the mold may be decreased to as low as 2 to 5 minutes each for thin laminates. The resin manufacturer should be consulted for recommendations on this subject particularly.

After the molding step the finishing operations of machining, assembly and packing follow in sequence.

Good design of molds and good shop practice should minimize machining operations. Color or patterns from embossed dies can be accomplished during the curing cycle, thus requiring no additional finishing costs for painting and the like. Conveyor belts and other mechanized techniques will materially aid in lowering production costs so that a larger volume market may be realized.

The Heath Co., Benton Harbor, Michigan, has made Fiberglas-reinforced seaplane floats. They are molded in two sections, so that the bottom section can be replaced readily, should damage

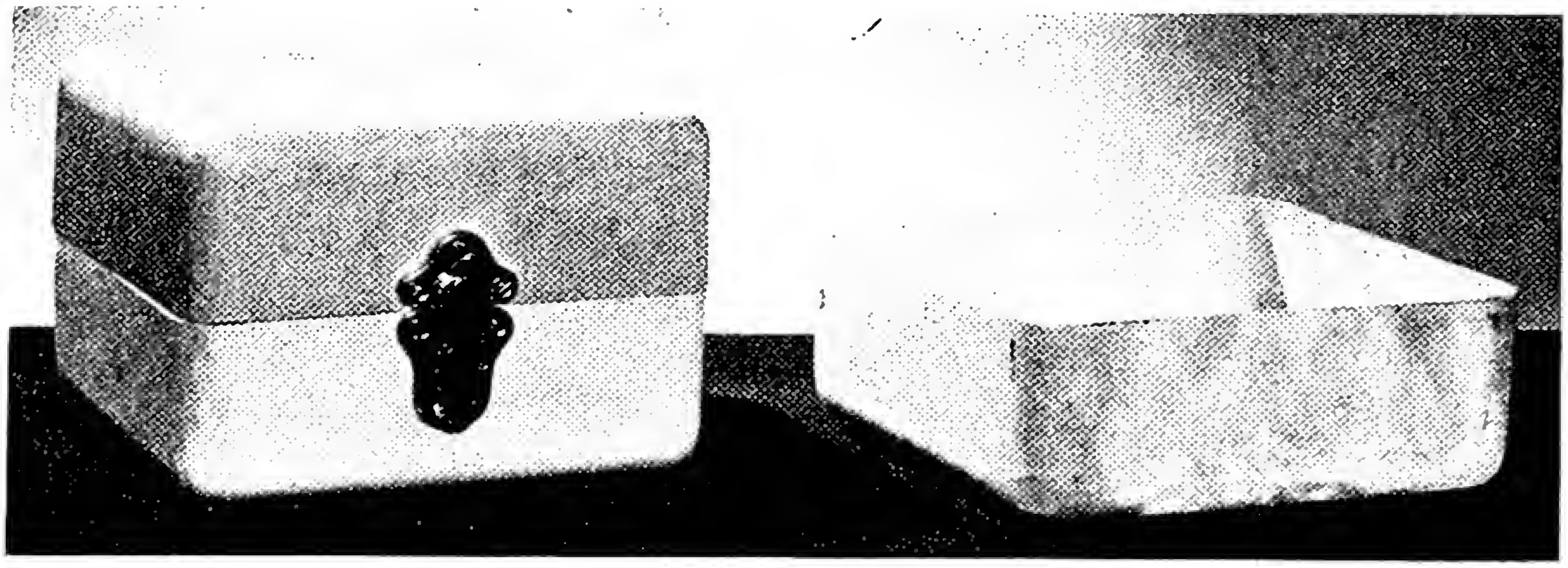


FIGURE 83. Box after trimming. Two such boxes have been assembled, with hinges and a lock to make the container shown on the left.

FIGURE 84. Thermoplastic sheet in a heating drawer.

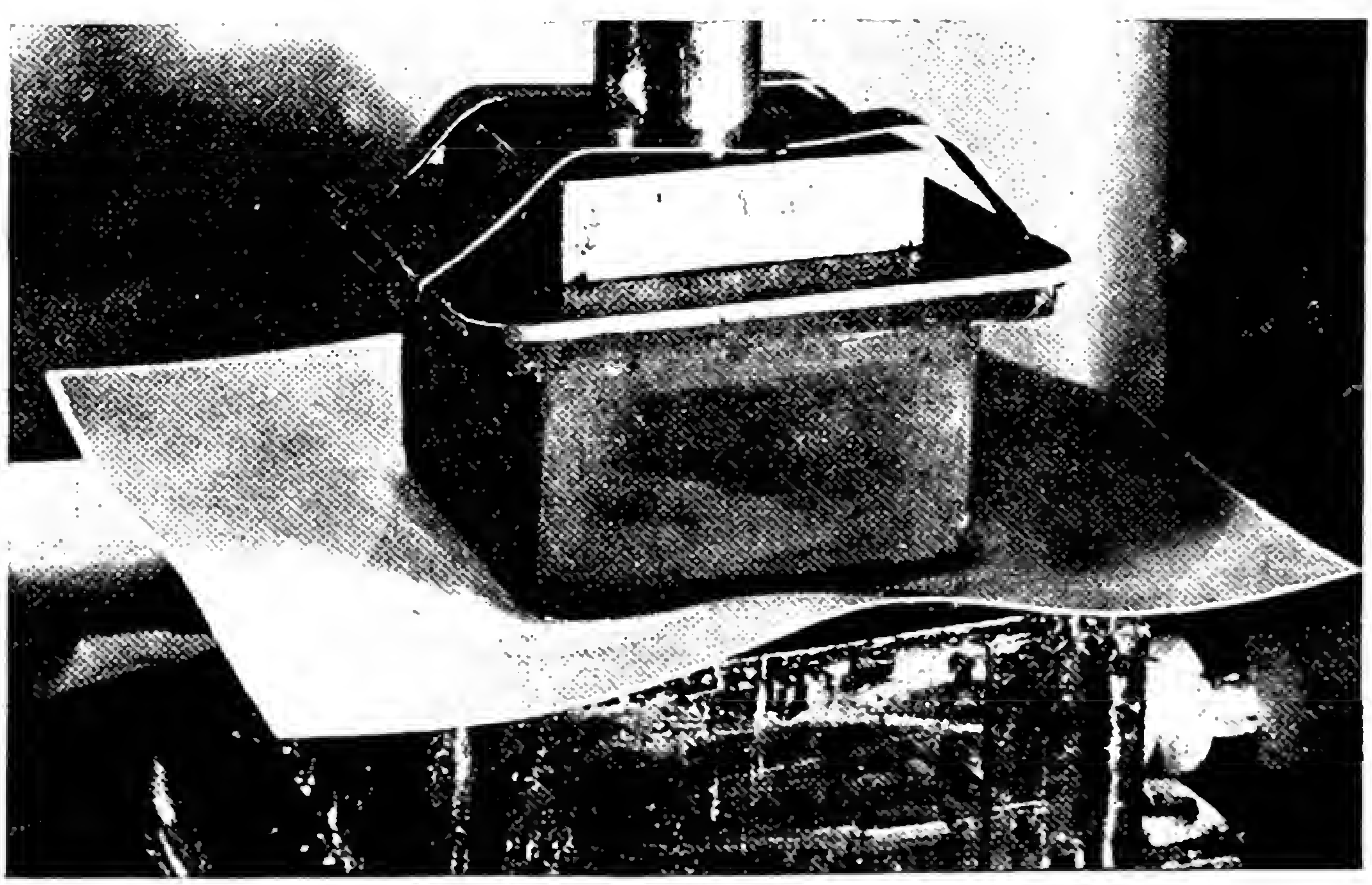


FIGURE 85. Pliable sheet in the rubber plunger press prior to forming.

occur. Alignment problems are eliminated by use of a ball-and-socket attaching gear. When the throttle is opened the floats automatically come up on the step.

A number of promising applications for reinforced plastics are now being developed and expanded. These include the following:

Aircraft gasoline tanks
Aircraft tooling
Airplane floats
Arch supports
Assembly fixtures for aircraft
Bows and arrows for archery
Bumpers
Cargo liners for planes
Containers
Decorative panels for furniture and sales counters
Display stands
Engine cowling
Fan blades
Fenders
Film carrying cases
Fishing rods
Ice bowls
Label holders
Lamp shades
Luggage
Molds for electronic curing of rubber
Phototemplate sheets
Propeller hub cowling
Propellers
Protective hats
Radio cabinets
Radomes
Refrigerator inner door liners
Routing fixtures
Seaplane floats
Shields for lighting
Signs
Sporting equipment
Stabilizer tips
Station wagon doors, tops
Switch box cover plates
Table tops
Trailer interiors
Venetian blinds
Wall paneling
Water tanks
Wheel fairings
Wing tips

Hydraulic presses are manufactured or sold by:

Birdsboro Steel Foundry & Machine Co., Birdsboro, Pennsylvania.
H. T. Kennedy Co., Inc., 30 Church St., New York 7, New York.
Baldwin Locomotive Works, Locomotive & Southwark Division, Philadelphia 42, Pennsylvania.
Denison Engineering Co., 1176 Dublin Road, Columbus 16, Ohio.

Chapter 7
Joining and Machining of Plastics

Joining and Bonding

Many objects may be made in one piece, but often it is desirable to join two or more plastic laminates. For best results the laminator should, as far as possible, follow the resin manufacturer's recommendations as to curing time and temperature, percentage of catalyst to use and molding pressure.

Damages to plastic parts may require repair rather than replacement. A simple arrangement for such repairing is to sand the damaged area, fill in with reinforcing material and compatible resin, and finally cure under low pressure of 5 to 10 psi. The pressure may be obtained by use of a small rubber blanket sealed at the edges with adhesive tape, and hooked up by means of a valve stem to a portable vacuum pump. Heat may be applied by means of an infrared lamp to objects too large to place in an oven. For scarf joints of laminates, the smaller the scarf angle the greater the resulting tensile and flexural strengths. Tensile loads should be applied with the laminations and not across their faces. Both lap joints and butt joints are used for atttachment by bonding or gluing.

Because a shear-type joint is loaded more uniformly than a tension bond, it is preferable to design a bonded joint so that the glue line or bond is subjected to shear stresses rather than tensile stresses.

Roughening the laminate surfaces results in a better bond than glossy surfaces. Addition of uncured impregnated reinforcing agent between the cured pieces of laminate improves the bond.

Some pressure, such as 5 to 50 psi on the parts being bonded, reduces the tendency to form pools of resin or trapped air pockets. A better bond results.

Mechanical fastening may be accomplished by bolted joints in which washers are used, or by riveting. Hollow type rivets are

preferred to solid rivets, which expand and cause crazing and delamination at the edges of the hole.

The demand for a fastener that could be installed by one operation from one side of any application led to the development of the Cherry Blind Rivet. Such a fastener is easy to install, has strength values comparable with solid rivets, and is free from critical tolerances. This rivet is an assembly of two members: a special rivet with a hole through it and a stem which is assembled into the hole. It is upset by pulling the stem into the hollow member with a pulling action created by either a pneumatic or a manual gun. Such rivets are suitable for fastening plastics, enamel-coated surfaces and other brittle materials. There is no material spoilage due to uncontrolled shank expansion, no marring of sensitive surfaces and no cracking or chipping. The rivets can be colored to match or contrast with the assembly. The plastics parts may be riveted together or riveted to metal or other materials. They are made in three types—self-plugging, regular hollow and pull-through hollow. Various metals and standard diameters in different grip lengths are available. The supplier is:

Cherry Rivet Company, 231 Winston St., Los Angeles 13, California.

Another type of fastener which has been widely used on airplanes and is suitable for attaching plastics is the "Dzus" fastener manufactured by:

Dzus Fastener Co., Inc., Babylon, N. Y.

A number of glues and adhesives are available. Some suppliers of these are:

American Cyanamid Co., Plastics Div., 30 Rockefeller Plaza, New York 20, N. Y.	Melurac 300
Bakelite Corp., 30 E. 42 St., New York 17, N. Y.	Vinylseal
Catalin Corp., New York, N. Y.	Catabond
Central Process Corp., Forest Park, Ill.	Superbond, Everlite
Consolidated Vultee Aircraft Co., San Diego, California	Metlbond
Cycleweld Div. Dodge Motors, 8021 Conant Rd., Detroit 31, Michigan	Cycleweld 55-6
General Electric Co., Plastics Div., Pittsfield, Mass.	Textolite

B. F. Goodrich Co., Koroseal Div., 500 S. Main St., Akron 18, Ohio	Plastilock 500
Heresite & Chemical Co., Manitowoc, Wisconsin	Heresite
Le Page's, Inc., 40 Swanson St., Gloucester, Mass.	LePage's Resin Adhesive
Minn. Mining & Mfg. Co., 900 Fauquier Ave., St. Paul, Minn.	3-M Adhesives
National Adhesives, Div. Nat'l. Prod., Inc., 270 Madison Ave., New York 16, N. Y.	Resyn adhesive 0-3605
Pennsylvania Coal Products Co., Petrolia, Pa.	Penacolite G-1124, G-1215
Resinous Prod. & Chemical Co., Inc., 222 W. Washington St., Philadelphia, Pa.	Redux; Uformite 430 & CB-552
U. S. Plywood Corp., 55 W. 44 St., New York 18, N. Y.	Weldwood; Cordo

Drilling

High-speed steel drills should be kept sharp for drilling reinforced plastics. Special drills with highly polished spiral flutes are desirable to give free exit to the chips. Rapid production is possible when drill presses run at 10,000 to 12,000 rpm.

Use of multiple head drill presses extends the life of drills by allowing two drills to cool while the third is being used. An automatic tripper moves drill No. 2 into the "action position" at the end of the cycle following use of drill No. 1. Such a multiple head also permits three different drilling operations, to be done in rapid succession.

Punching

Dies used for punching reinforced plastics are very similar to those used for punching metal. Clearances between the punch and the die must be considerably less than for metal. Either hot or cold punching can be done. Dies must be kept sharp for best results. Strippers are close fitting and backed by strong springs. Often there is a shrinkage in diameter of punched holes, in which case the size of the punch should be 0.001″ larger for every 0.015″ thickness of material, punched hot, and 0.001″ larger for every 0.020″ thickness of material, punched cold. Heating prior to punching should be uniform throughout the laminate.

Sawing

Band or circular saws may be used for cutting reinforced plastics. A hard steel saw is preferable. For heavy sawing, high-carbon saws are best adapted to the work. Operating speeds vary from 2000 to 3000 feet per minute, depending on the nature of the plastic to be cut.

Reference

"High Velocity Simplifies Band Sawing," by H. J. Chamberland, *Modern Plastics*, p. 146 (March, 1946).

Threading and Tapping

For standard pitch and depth, milling is recommended rather than the use of dies or even single point tools. Such milling cutters should operate at high speed and should be of high-speed steel with plenty of clearance. Drills should be lifted from the work frequently to prevent dulling caused by excessive heating.

Tight fits are obtained when standard taps are used. Use an oversize tap of about 0.002″ for a loose fit. Metal inserts are preferable if the threads are to be used frequently. They can be molded in the laminate during the curing cycle.

Turning and Milling

Higher speeds should be used for working reinforced plastics than commonly used for other types of material. Carbide-tipped tools will usually be found advantageous. Good finishes and accurate dimensions can be produced with Stellite.

The milling cutter should be larger in diameter and have two or three times as many teeth as commonly found on a metal-working cutter. Speeds and feeds are similar to those for bronze and soft steel.

References

"Machining Polystyrene," by Mel Meyers, *Plastics*, p. 56 (Feb., 1946).

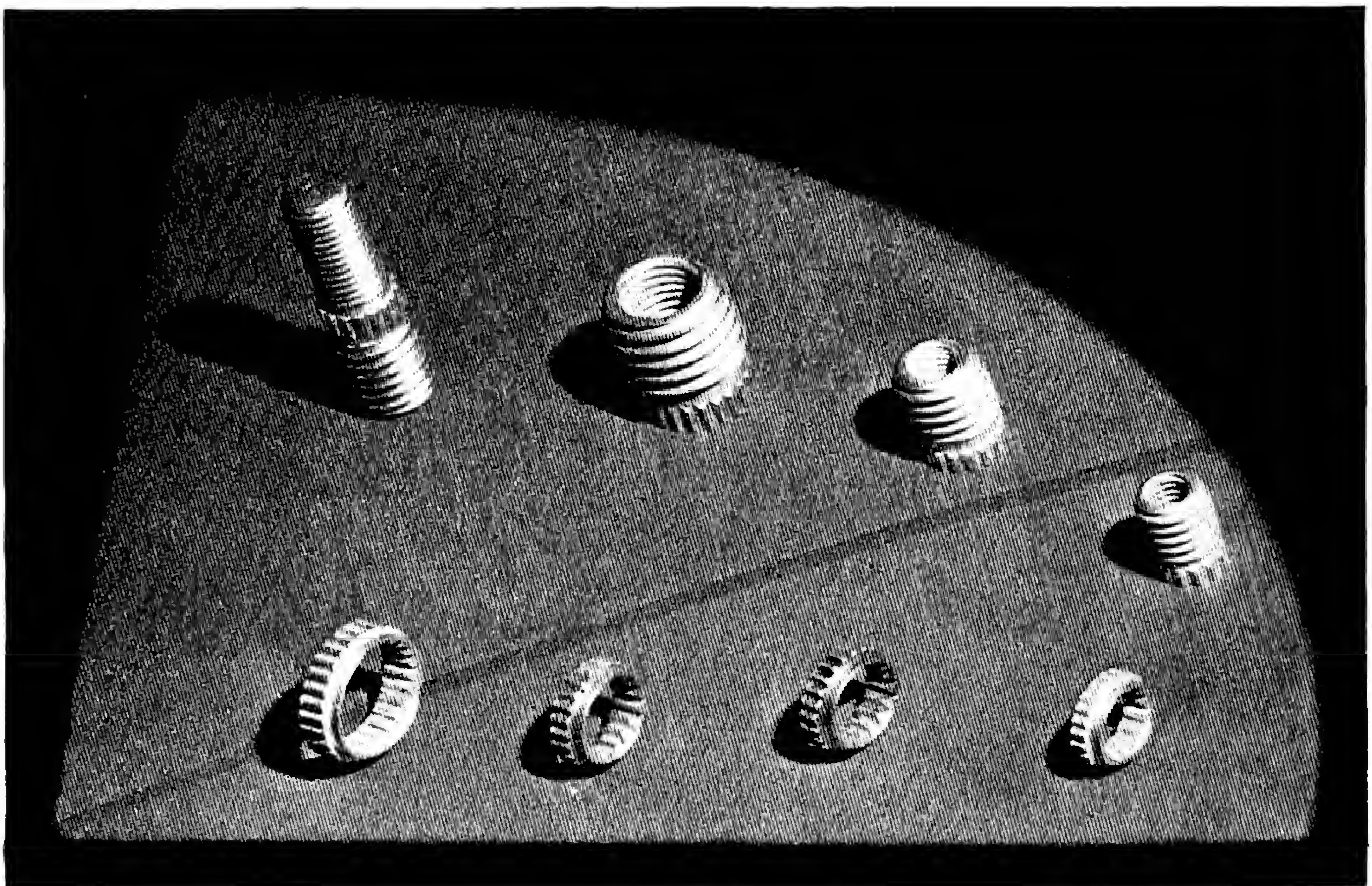
"Machining Fiberglas Reinforced Plastics," by Frank E. Allen, *Industrial Plastics*, p. 10 (July, 1945).

"Glass Fabric Melamine Resin Laminates," by C. J. Straka, *Plastics*, p. 62 (August, 1946).

"Machining Plastics with Carbide-tipped Tools," by Carroll Edgar and Harold York, *Pacific Plastics*, p. 22 (December 1946).

Metal Inserts and Studs

The Rosan locking system for threaded inserts and studs is simple. A lock ring, accurately serrated both inside and out, engages its inner teeth with a mated serrated color on the insert or stud. The outer teeth of the locking ring broach their way into the parent material at the surface of a counterbore when driven or



Courtesy National Screw & Mfg. Co., Cleveland, Ohio

FIGURE 86. Rosan metal inserts and studs.

pressed into place. This makes the insert or stud an integral part of the parent material and creates a completely permanent installation. Both inserts and studs may be readily removed for replacement without injury to the parent material. They are manufactured by:

The National Screw & Manufacturing Co., 2440 East 75th St., Cleveland 4, Ohio.

Drive screws and self-tapping screws may be obtained from:

Parker-Kalon Corp., 194 Varick St., New York 14, N. Y.

Chapter 8
Product Analysis: Engineering and Cost Principles

If a product is now being made from plastics in which the high-pressure molding technique is used, and that product performs its function rather satisfactorily, then it is practically axiomatic that low-pressure laminates do not belong in that particular field. This is not because the product cannot be made by the low-pressure technique, but because usually the higher cost of a laminate as now made by much more expensive processes and of more expensive resins cannot compete. This is no criticism of the new material, but is rather a suggestion for seeking the right market applications and for improving the processes used for fabrication.

If the present product can be made from sheet metal, *e.g.*, steel or aluminum, then one may figure the cost per unit, based on tools, dies, jigs and fixtures required for the working of the metal plus the low cost of the metal. Tools and dies are the expensive part in fabricating metals. For example, a new model car may require ten million dollars for tools, dies and related equipment; but, if a million of these cars are manufactured, the cost is increased only ten dollars each for the tooling. If only 10,000 units were to be made from such tooling, then the unit cost for the tooling would be $1,000.00, or prohibitively high in the present competitive state of mass production of automobiles.

These remarks lead to the problem of considering the fabrication of a given product in metal versus fabrication in a reinforced plastic low-pressure laminate. A number of analyses of tool costs indicate that if one intends to make 4500 to 5000 items, it is just as cheap to tool up for fabrication from sheet metal as it is to make them from low-pressure resins and reinforcing agents. When the number of items to be produced is small, such as several hundred or even one or two thousand, it is likely that the unit manufacturing cost will be lower in a reinforced plastic low-pressure laminate.

This is the second axiomatic statement concerned with product analysis.

Illustrative of the first axiom that present molded products give satisfactory performance, one should consult the standard stock catalogs of molds already made for hundreds of items useful in commerce. In such a case the fabricator has probably written off the initial mold cost with the first large order, so that re-orders may be filled for a much lower cost per unit.

Reference

"Plastics Stock Molds," a catalog of stock molded parts, extrusions and laminates, compiled by the Stock Mold Department of *Modern Plastics*, 122 East 42nd St., New York 17, N. Y.

Comparative Weights of Structural Materials and Plastics

Material	Approximate Weight (lbs. per cu. ft.)
CCA, Styrofoam & Rubatex Core Mat'ls.	2 to 8
Wood	36
Polystyrene	67
Ethylcellulose	71
Nylon	72
Cellulose acetate-butyrate	73
Methyl methyacrylate	74
Molding phenolic	78
Cast phenolic	82
Cellulose acetate	83
Cellulose nitrate	86
Polyvinyl plastics	88
Urea plastics	92
Melamine	93
Saran	104
Heat-resistant phenolic	112
Brick	112
Magnesium Alloys	112
Window Glass	160
Plate Glass	160
Aluminum Alloys	174
Cement	180
Zinc	442
Cast Iron	450
Tin	455
Steel	490
Brass	530
Bronze	550
Nickel	555
Copper	555
Lead	705

Now in production is one of the largest compression moldings, a housing for a five-tube radio-phonograph, the first of its type ever produced. Brass inserts and all holes are molded in. The size of the finished automatic record player cabinet is $16\frac{3}{4}''$ x $14\frac{3}{4}''$ x $6\frac{3}{4}''$. This is another item to add to the long list of high-pressure molded articles. For mass production, therefore, this application should be stricken from the list of probable applications of low-pressure laminates.

Though transparent polystyrene costs about the same as window glass on an equal volume basis, it should not be concluded that store windows are a logical application. Other characteristics of the

Comparative Prices of Structural Materials and Plastics

Material		Approximate Price Per Cu. Ft.
Brick	less than	$ 1.00
Cement	less than	1.00
Wood	less than	1.00
Cast iron		6.00
Window glass		10.00
Core materials-CCA, Styrofoam, Rubatex		10.00
Molding phenolics		14.00
Steel		16.00
Polystyrene		19.00
Heat-resistant phenolics		20.00
Plate glass		24.00
Cellulose nitrate		26.00
Urea		26.00
Cellulose acetate		31.00
Cellulose acetate-butyrate		33.00
Ethylcellulose		37.00
Polyvinyl plastics		37.00
Zinc		38.00
Polyvinyl chloride plastics		42.00
Melamine		42.00
Magnesium alloys		43.00
Cast phenolics		45.00
Lead		46.00
Aluminum alloys		50.00
Saran		52.00
Methyl methacrylate		63.00
Brass		68.00
Copper		69.00
Bronze		77.00
Nylon		115.00
Nickel		195.00
Tin		236.00

functional application are important, *viz.*, differences in strength per unit volume and comparative surface hardnesses.

Every producer of mechanical equipment should be familiar with the rapid and inexpensive technique of designing and manufacturing parts made from glass-reinforced plastics. Small numbers of parts with complicated contours can be run without incurring prohibitive die and mold costs. This is illustrated by the bottle-label holder shown in Figures 87 and 88. This item was required in very small quantities for packaging or labeling machines. The cost of dies for only a few metal stampings would be prohibitive. A combination of metal flat sheets and contoured reinforced plastic parts makes an ideal low cost solution to the problem.

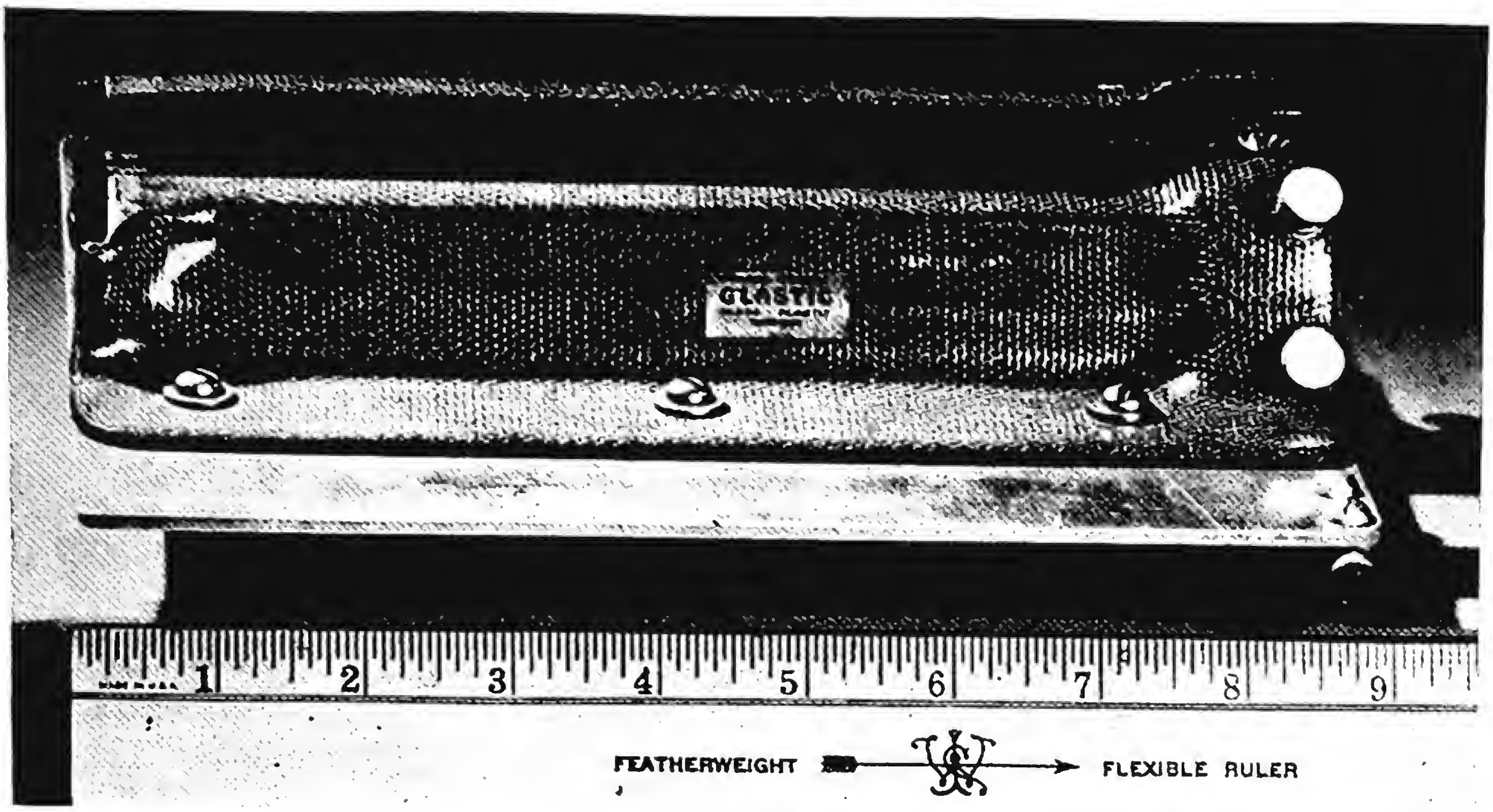
Reference

"Precision Labeling with Reinforced Plastics," by Prescott Fuller, *Modern Plastics,* p. 98 (May, 1946).

Another illustration of a sound application for reinforced plastics is in its use as a face material of a stretching die. In such a case the high cost of tooling in the conventional manner for sheet-metal stamping is avoided. Figures 89-92 show the lamination of a glass-reinforced surface for such a die. Such a surface may be used on a new die to make it stronger, or as a covering on old dies to prolong their useful life very substantially. It is probable that such low-cost dies may be used widely to replace the much more expensive metal dies used for stamping and drawing of sheet metal.

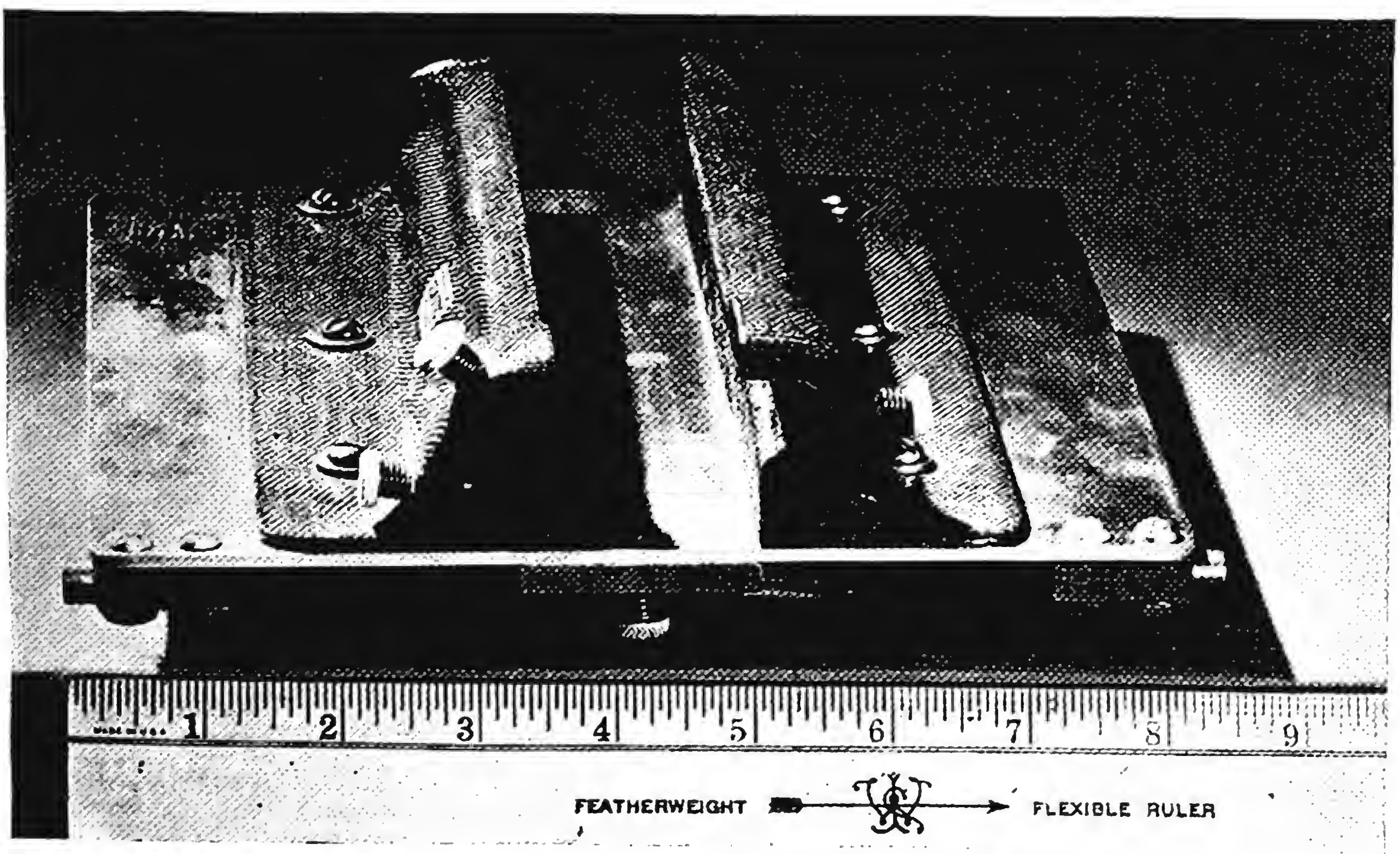
One qualification should be mentioned regarding the "break-point" in volume production of sheet metal parts versus low pressure laminated parts. The figure of 4500 to 5000 items has been cited. Such a number *contemplates* contoured parts of a size, larger than is now practical for forming by high pressure molding techniques. Such a number also *assumes* that the manufacturer has a plant already equipped with presses and related facilities for the production of metal stampings.

Let us suppose that the problem contemplates such contoured parts but there are no plant facilities whatsoever. Economic analysis of this situation indicates that the "break-point" in volume reinforced plastics production versus sheet metal parts is *far higher* than 5000 items. The figure might be 10,000 or 50,000 or even higher, depending on the application and other variables.



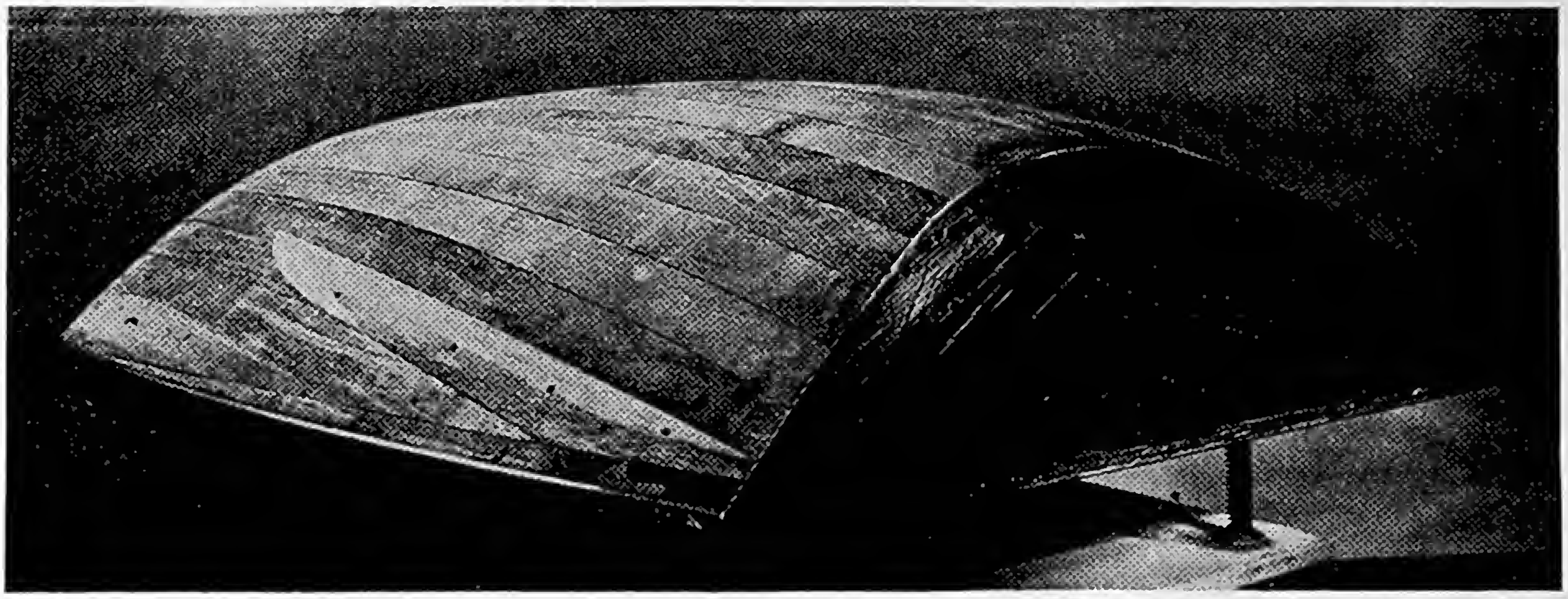
Courtesy Laminated Plastics Co., Cleveland, Ohio

FIGURE 87. Bottle label holder. Flat aluminum sheet with formed parts made of Fiberglas reinforced plastic. #162 Fiberglas cloth was used with Laminac 4201 resin.



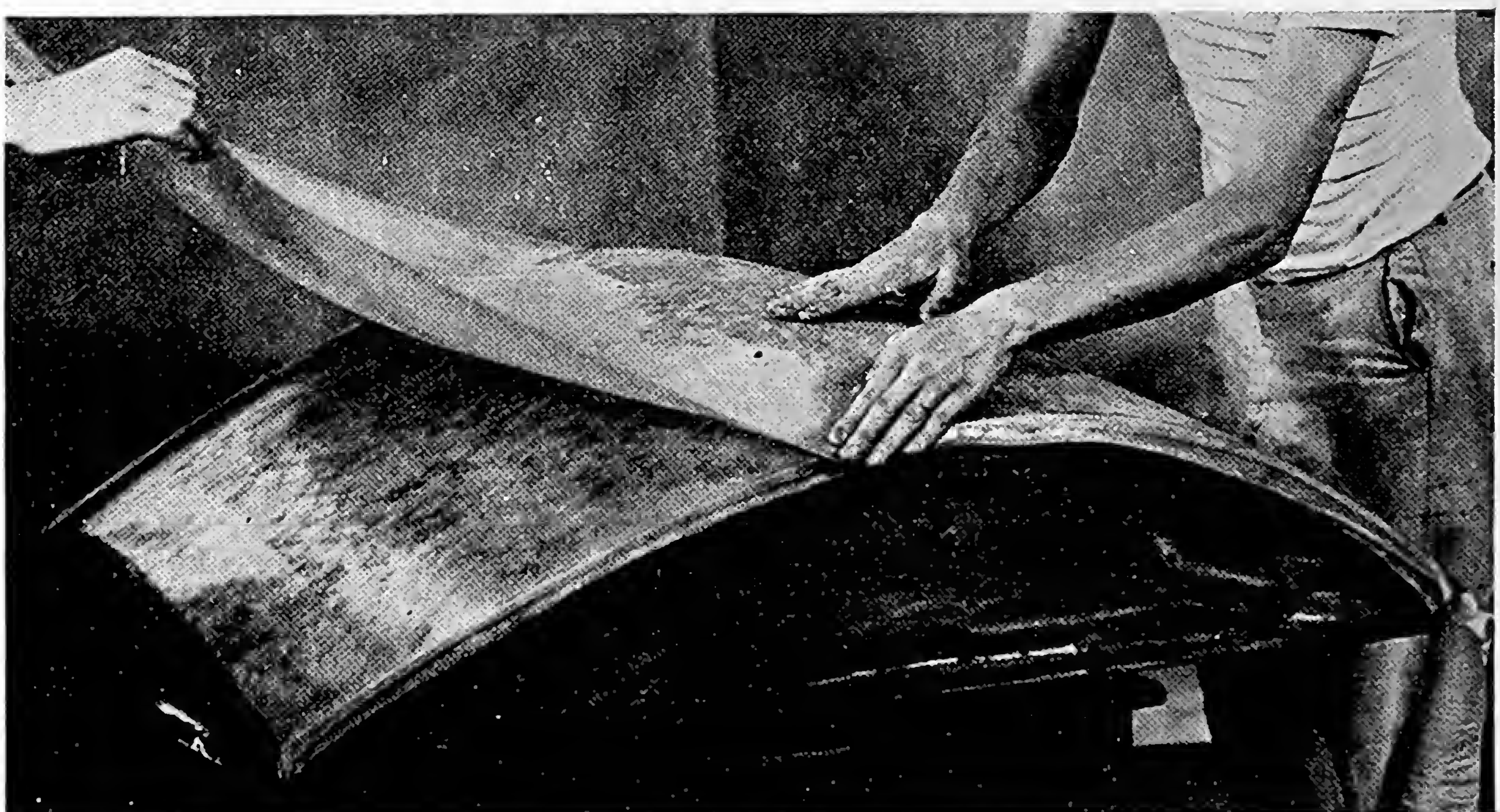
Courtesy Laminated Plastics Co., Cleveland, Ohio

FIGURE 88. Bottle label holder.



Courtesy Flxible Co., Loudonville, Ohio

FIGURE 89. A typical wooden die used for stretching sheet metal into desired shapes. This system is in use for production of metal parts in quantities too few to justify expensive metal tooling. The die is used as a mold on whch to lay up the laminate.

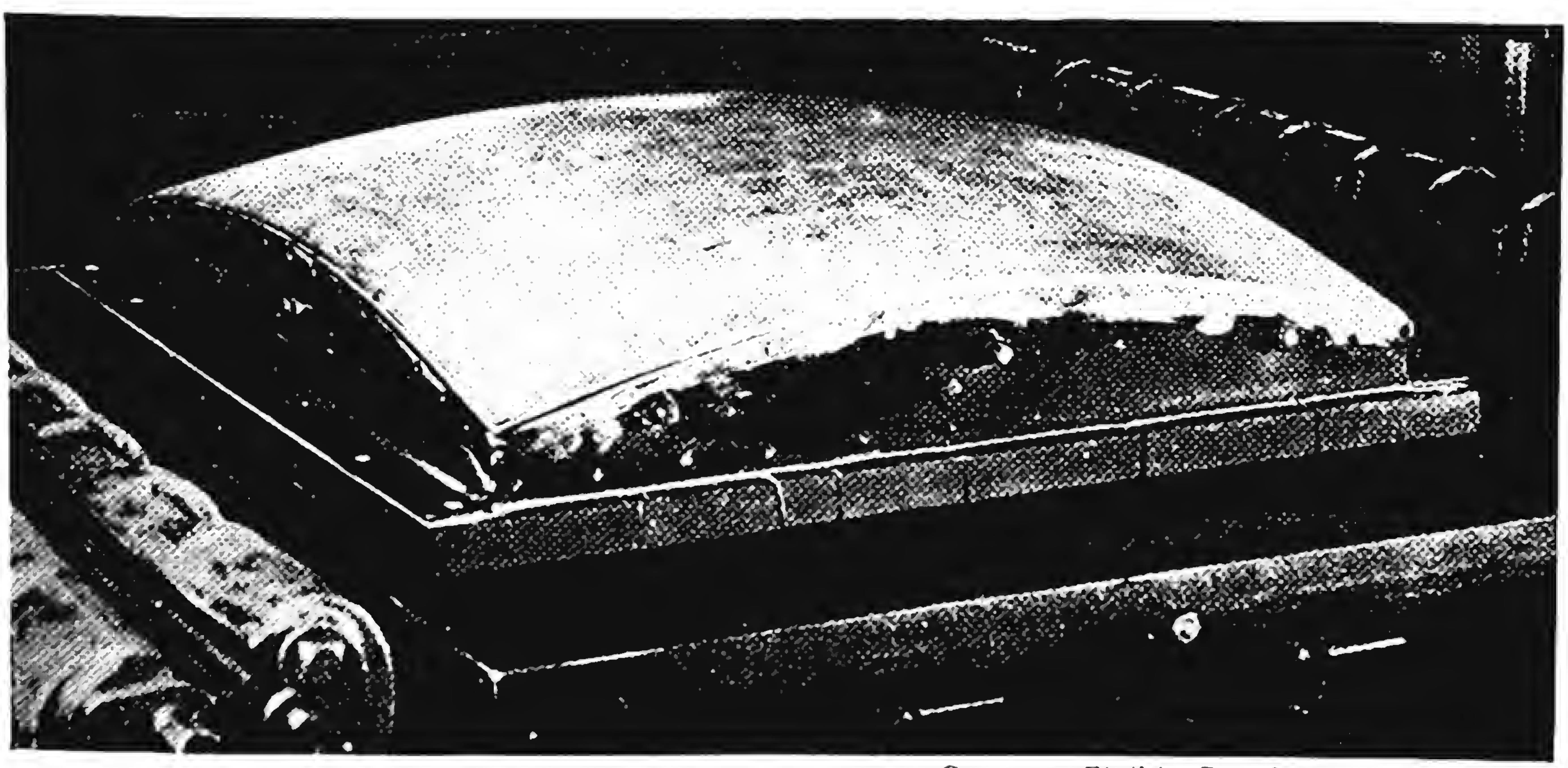


Courtesy Flxible Co., Loudonville, Ohio

FIGURE 90. Laying up of resin coated glass cloth on a typical stretching die. Eight plies of Fiberglas cloth ECC-128 were used.

Courtesy Flxible Co., Loudonville, Ohio

FIGURE 91. Placing the polyvinyl alcohol (PVA) bag over the mold and laminate prior to curing. The vacuum hose and connection to the bag is shown. The white areas are "bleeder strips" to prevent the sealing off of areas.



Courtesy Flxible Co., Loudonville, Ohio

FIGURE 92. Showing the reinforced plastics stretching die after 120 pieces of sheet metal had been drawn. The surface shows no perceptible wear. Metal edging which holds laminate in place is visible here.

Perhaps there are a number of reasons why the large scale production of low pressure laminated parts in the automotive field has been delayed until very recently. The *fact* that the first 10,000 fenders for a trailer have been made and delivered should be very significant to those who peer into the future of plastics.

These plastic fenders are of sandwich construction, consisting of a $\frac{1}{4}$ inch layer of jute felt matting placed between two layers of Fiberglas mat T34-A. Patterns measuring 6 ft.$\times$18 in. are first cut to size, laid between two wire screens, impregnated with Laminac 4201 resin, passed through squeeze rollers to remove excess resin, and cured in cast aluminum molds at 250°-275° F. and 5 psi in a 10-minute cure cycle. The fender is finished and painted. A complete illustrated report of this application may be found in the reference cited.

Reference:

"Low-Pressure Laminated Fenders for Trailers in Large-Scale Production by Western Plant," *Pacific Plastics*, pp. 16-17 (December, 1946).

Costs

There are two basic approaches to the problem of estimating the cost of a reinforced plastic.

On the *area* basis or cost per square foot figure the cost of the required plies of reinforcing material. For rough calculation assume the same weight of resin at 50c per lb. This gives material cost to which should be added at least 100 per cent for fabrication cost. This value is the minimum overhead. In many cases 150 per cent or more may be required. The final figure is the selling price by the laminator to his customer. If this is a consumer item it is not unusual to double this figure for the retail selling price or list price.

On the *weight* basis one can usually figure the reinforced plastic part to be $\frac{1}{5}$ the weight of steel or $\frac{3}{5}$ the weight of aluminum in the part. For cotton duck or glass plus resin, figure about \$1.00 per pound, for the selling price of the laminate by the fabricator. The list price through retail outlets would thus be \$1.50 to \$2.00 per pound based on the weight of the merchantable item.

The properties of plastics vary as widely as those of metals. Lack of understanding of the various properties obtainable in plastics has unfortunately resulted in misapplications.

Low-pressure laminating of plastics is a simplified procedure particularly for large parts and those involving compound curves. Frequent design changes are possible because tooling costs are much lower than for working in sheet metal. In fact, it is uneconomic to undertake the heavy investment in costly dies for metal fabrication of many such parts.

It has been reported that each pound of weight saved in commercial airplanes is worth $100 per year saving in operating cost. Such applications are most attractive for use of reinforced plastics which are so light and so strong.

Application	Estimated Value of Weight Saving per Year
Commercial airplanes	$100.00 per lb.
Motor trucks	1.00 per lb.
Railroad rolling stock	.50 per lb.

There are many variables to be considered: the choice of the proper resin, the proper reinforcement material, the proper fabrication technique and curing cycle.

An example of product engineering—a combination of sales needs, technical needs for performance and limitations of molding —is shown in the story of the development of an electric razor with many plastic parts.

Reference

"The Schick Shaver—A Case History," by William Schack, *Plastics*, p. 34 (April, 1946).

The following table shows some comparative properties of several reinforced plastic materials, steel, light alloys and wood.

Material	Specific Gravity	Tensile Strength (psi)	Compressive Strength (psi)	Modulus of Elasticity in Tension (psi)	Modulus of Elasticity in Compression (psi)
Cotton-reinforced plastic	1.38	12,000	35,000	1,020,000	580,000
Glass-reinforced plastic	1.7	45,000	40.000	1.800.000	2,000,000
Paper-reinforced plastic	1.35	14,000	35,000	1.380,000	700,000
Rope-reinforced plastic (low density)	1.2	9,000	20,000	—	—
Stainless steel	7.85	185,000	150,000	30,000,000	30,000,000
Chrome-molybdenum steel (heat-treated)	7.85	180,000	150,000	29,000,000	29,000,000
Aluminum alloy (24-ST)	2.80	62,000	22,100	10,400,000	10,400,000
Magnesium alloy (AM-585)	1.81	46,000	35,000	6,500,000	6,500,000
Aircraft spruce (Douglas fir)	0.43	10,000	5,000	1,300,000	1,300,000
Birch plywood	0.80	13,100	5,700	1,400,000	—

Specific tensile strength may be calculated from such data by dividing the tensile strength (psi) by the specific gravity. Thus for stainless steel, 185,000 divided by 7.85 is approximately 23,700 psi, and for glass plastic, 45,000 divided by 1.7 is 26,470 psi, a specific tensile strength greater than for steel. This is why it is said that on an equal weight basis glass-reinforced plastics are stronger than steel. Further, one may so design the glass reinforcement and fabricate the laminate as to take the stresses in the direction and planes desired. Thus the designer may build greater strength along with lighter weight, using inexpensive tools and molds for large objects of any shape.

Specific compressive strength may be found by dividing the compressive strength (psi) by the specific gravity of a given substance. Other specific values may be similarly calculated. In such a fashion one reduces the values of strengths of materials to the same weight basis for comparison, which takes into account the great difference in specific gravity. In fact it is a comparison of strengths on a volume basis—an important feature in airplanes, ships, submarines and like places where volumetric space is at a premium. When the designer asks, "How can we make it stronger without increasing its volume?" he can use steel to replace aluminum. But if he asks, "How can we make it stronger without increasing its weight?" he can check a table of *specific strengths.* There he will probably find glass (proper kind) -reinforced plastics topping the list.

Resins alone have low values for tensile strength and compressive strength. Some resins have a high modulus of elasticity and are very brittle. Other resins, which are flexible, have very low moduli of elasticity.

The formulator may combine a thermosetting with a thermoplastic resin for dual properties. There must be compatibility of resins or mutual solubility within the percentage range being used. The ratio of resin and reinforcing material may vary from 35 to 60 per cent resin and 65 to 40 per cent reinforcing material.

The following table shows a comparison of several types of phenolics and urea resins for a number of qualities shown in the headings for the vertical columns. The relative properties shown in this chart are based on both laboratory tests and experience gained by application of the plastics in general service to many

MOLDING PLASTICS COMPARATOR

	Shock Resistance (Impact—Izod)	Tensile Strength	Flexural Strength	Cold Flow	Hardness (Rockwell)	Heat Resistance (Utility under Continuous Heat)	Dimensional Change on Aging	Thermal Insulation	Specific Gravity	Flammability	Color Possibilities	Color Stability	Utility Around Inserts	Ease of Molding	Water Resistance (Absorption)	Alkali Resistance	Acid Resistance	Organic Solvent Resistance	Loss Factor 60 cycles/sec.	Loss Factor Megacycle/sec.	Resistivity	Dielectric Strength
Phenolics General-purpose	3	1	3	1	2	2	4	1	2	4	2	2	3	1	4	3	3	2	3	2	3	3
Phenolics Low-loss	3	2	5	1	2	3	2	2	4	2	4	4	3	3	1	2	2	2	1	1	1	1
Phenolics Heat-resistant	5	6	6	1	2	1	1	2	4	1	4	3	2	3	2	2	2	2	5	4	5	5
Phenolics Heat-resistant with improved impact	2	3	1	1	2	1	1	2	4	1	4	3	1	4	2	2	2	2	5	4	5	5
Phenolics Acid-resistant; Alkali-resistant	5	5	4	1	1	3	3	1	1	3	3	3	4	2	3	1	1	1	3	2	2	3
Phenolics Medium shock-resistant	2	4	3	1	2	4	5	1	2	5	4	3	1	3	5	3	3	2	4	3	4	4
Phenolics High shock-resistant	1	4	4	1	2	4	5	1	2	5	4	3	1	4	5	3	3	2	4	3	4	4
Urea	4	1	2	1	1	5	6	1	3	3	1	1	5	2	4	4	4	2	2	2	2	2

Nos. 1-6 represent highest to lowest in order of merit. Relationships are qualitative and variation in formulation may alter position on chart.

different applications. More experience is necessary in order to add various thermosetting resins used in the low-pressure field.

The fabricator considers the primary qualities or characteristics needed in the finished merchandise in order to select the proper type and grade of resin to use with the proper reinforcing material. Sometimes there are compromises made in the technical merit of materials used in order to meet cost requirements.

One resin manufacturer states the following four steps in their functional engineering of a resin to meet the *specific* requirements of the laminator's job: (1) Analysis of the problem followed by recommendations; (2) development of a resin for the particular application; (3) testing this resin on the job, in the laminator's plant, working with his operating men; (4) stabilizing its production for continuous uniformity in performance.

It is desirable to build into the product as much functional performance per dollar as possible because this is so fundamental. The customer asks such questions as, "How long will it last?" "How much maintenance will be required over its service life?" and always compares the newly offered reinforced plastic article with the item which is now being used.

Characteristics of resins vary with the various manufacturers as well as different groups supplied by one company. For example, resins may be:

Air-sensitive or non-air-sensitive during curing
Designed for continuous laminating operations
For higher-temperature cures
Good to poor fire-retardant
Good to poor resistance to surface abrasion
High to low toughness and tear strength
Higher to lower moisture resistance
Long or short tank life (catalyst added)
Low distortion of laminate at higher temperatures (may be aided by heating the cured resin)
Low to high degree of tackiness to assist vertical "lay-up"
Low to high impact strengths
Low to high viscosity
Rigid or flexible resin
Solid or paste consistency
Slow to rapid curing type (short production cycles)

Reference

"Data on Low-Pressure Laminating Resins," prepared by York Research Corp., Plastics Division for Owens-Corning Fiberglas Corp., *Modern Plastics*, p. 144 (June, 1946).

The plastic automobile body is now more tangible than a sketch on the drawing board. Glass-reinforced plastics have been used in a new four-piece auto body designed by Howard Darrin, and produced by Industrial Plastics Corporation, Gardena, California.

Reference

"Low-Pressure Laminated Automobile Body is Lightweight, Durable and Good Looking," *Pacific Plastics*, p. 15 (August, 1946).

Looking to the Future

The storage life or "shelf life" of most resins is quite satisfactory. At room temperature under usual storage conditions the resin may be kept for a period of several weeks to many months in sealed containers such as 50-gal. drums. When the catalyst has been added to the resin, the shelf life at ordinary room temperature is very limited. For some resins, the storage period is limited to a few hours, after which the mix is unsuitable for use in preparing reinforced plastic laminates.

Storage of catalyzed resins at lower temperatures such as 40° F prolongs the useful "shelf life." It would be very desirable to have improved resins and catalysts so that they could be received already mixed, thus eliminating that operation and yet permitting good storage life. If the catalyst would remain inactive until a temperature of about 150° F is reached, at which point the catalyst would be "triggered" or become active, we would have a more foolproof product. That is something for the catalyst manufacturers to consider.

As to the resins, we can always seek improved weathering resistance and related qualities. A shorter curing cycle would be helpful from the production and cost standpoint, because mold cost and curing cost per unit would be correspondingly reduced.

Resins are usually colored with dyes or with pigments in order to lend color to the finished laminate. Thus far the choice of color is limited and fastness to sunlight is none too good. Some dyes discolor during the curing cycle; other dyes in laminates fade or bleach out upon exposure to sunlight. Much work remains to be done to

improve this feature. Surface painting of laminates is an expensive alternative at the present time.

A new allyl ester thermosetting resin (Kriston) has excellent clarity and very low shrinkage when cured. Its refractive index of 1.548 is higher than that of most optical glass. This adds impetus to the search for a transparent reinforced plastic with most of the advantages of window glass plus added strength so characteristic of low-pressure laminates. Using flexible resins one might produce "flexible" glass, a long-sought product. When colors are added to such a product, there may result a new type of "artificial leather," far more durable than patent leathers or thermoplastic sheeting.

Reference

U. S. Patent 2,311,613, "Transparent Composite Material," Feb. 16, 1943.

Another suggestion is to produce a light-weight reinforced plastic refrigerator. Let the whole inner box and door liner be made of a low-pressure laminated glass-reinforced plastic material which is easily washable, odorless, sanitary, and yet vapor-permeable. The characteristic of vapor transmission is desirable to prevent moisture buildup in the thermal insulating material. Water vapor moves away from the insulation through the plastic inner box wall, to be frozen on the cooling unit. It is removed regularly by defrosting. The outer box would be made of a reinforced plastic with a vapor barrier molded in. This barrier might be a thin sheet of metal molded integrally with the other plies of reinforcing material. Colors could be molded in the inner box as well as in the outer box so that the decorative color scheme would be carried out readily. It would appear that these same principles of design for refrigerators could be applicable just as well to industrial units as well as to domestic refrigeration units.

Improved techniques are desired to insure rapid, low-cost production of "glass" smooth surfaces in low-pressure laminates of colored low-pressure laminates by incorporation of dyes or pigments, and of pin-hole free low-pressure laminates with no air bubbles therein.

The ideal process of fabrication of a reinforced plastic should be simple and adapted to straight line mass production techniques. If the reinforcing material is pre-formed with the minimum effort,

catalyzed resin added quickly, a short curing cycle used with possible after-baking to complete the cure, then the lowest fabrication cost of a complete article should be realized. This should be a development in the not too far distant future.

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Appendix

Outline for Laboratory Experiments

Several laboratory sessions may well be spent on the lamination of plastics by low-pressure methods. These may be found useful for industrial companies, in sales personnel training schools, as well as in vocational subjects in high schools and junior colleges. It is an old proverb that states that one picture is worth a hundred words. This might be paraphrased to say that one good laboratory experiment, well taught, is worth a hundred pictures.

Chapter II on Molds, and Chapter III on Resins, Catalysts and Curing should be read before the laboratory work is undertaken. The material may be covered in lectures beforehand. Figures 93 to 100 illustrate the steps in laying-up a reinforced plastic boat model. (See following pages.)

Since the Pittsburgh Plate Glass Company, Pittsburgh 19, Pa., who manufacture Selectron resins, does recommend and supply colors, it is suggested that such resins be used for experiments with colored resins.

It is desirable for the laboratory instructor to perform the several desired experiments so that timing may proceed orderly through those selected.

Materials suggested for use:

Carver press with heated platens

Cast aluminum die with vacuum type self-sealing rubber blanket for a cover.

Cellophane and Silicone Grease #4.

Dyes and Pigments for Selectron Resins.

Fiberglas Cloth and mat (other cloths or mats may be used as reinforcing agents. (See chapter 4.)

PVA sheeting and valve stems for hose connections.

Rubber hose.

Selectron 5003 Resin and catalyst (other low pressure laminating resins may be used; see chapter 3).

Small Oven.

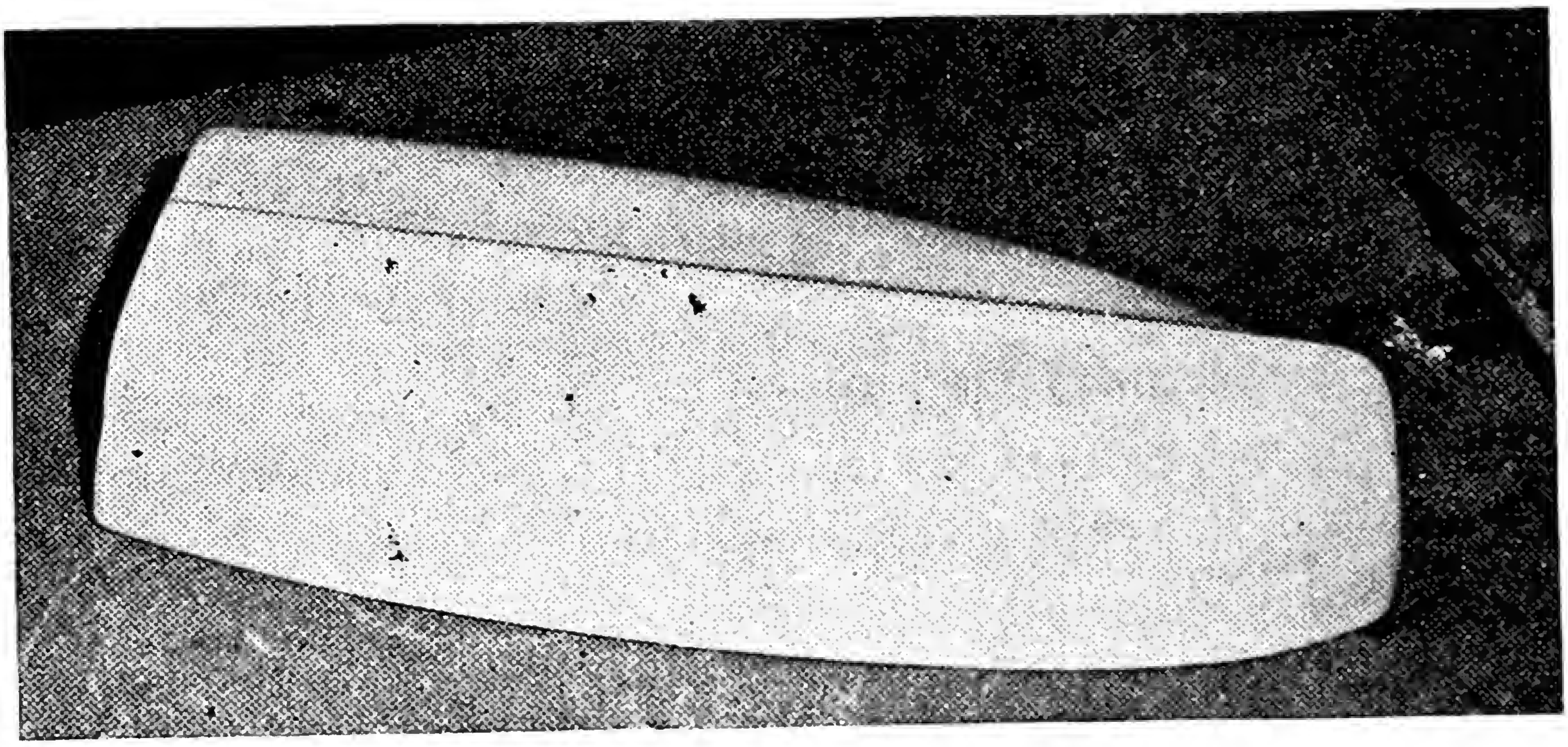

FIGURE 93. Plaster of Paris male mold for boat model.

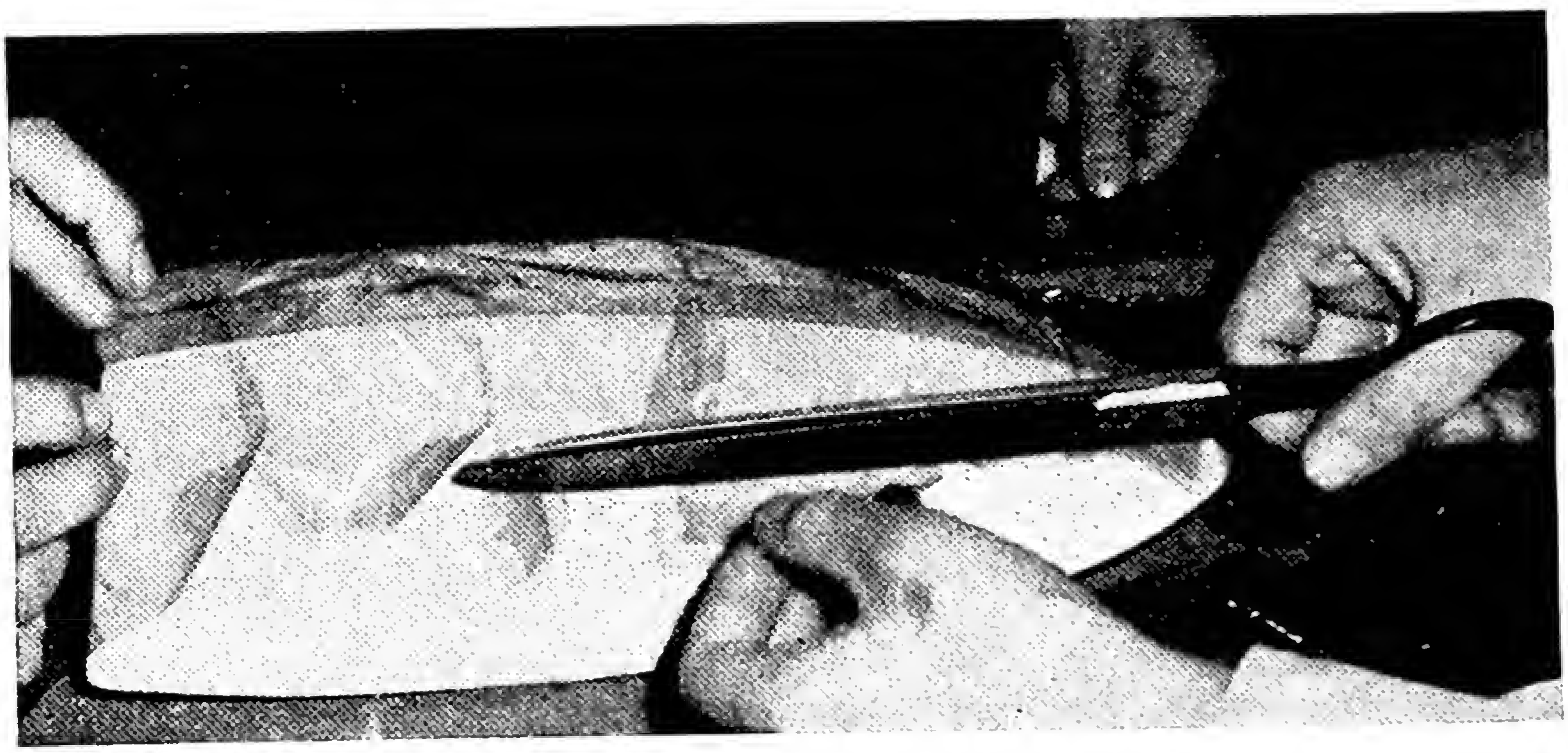

FIGURE 94. Placing cellophane strips over the mold, which serve as a parting agent or mold release.

FIGURE 95. Coating cloth with resin which contains the dissolved catalyst.

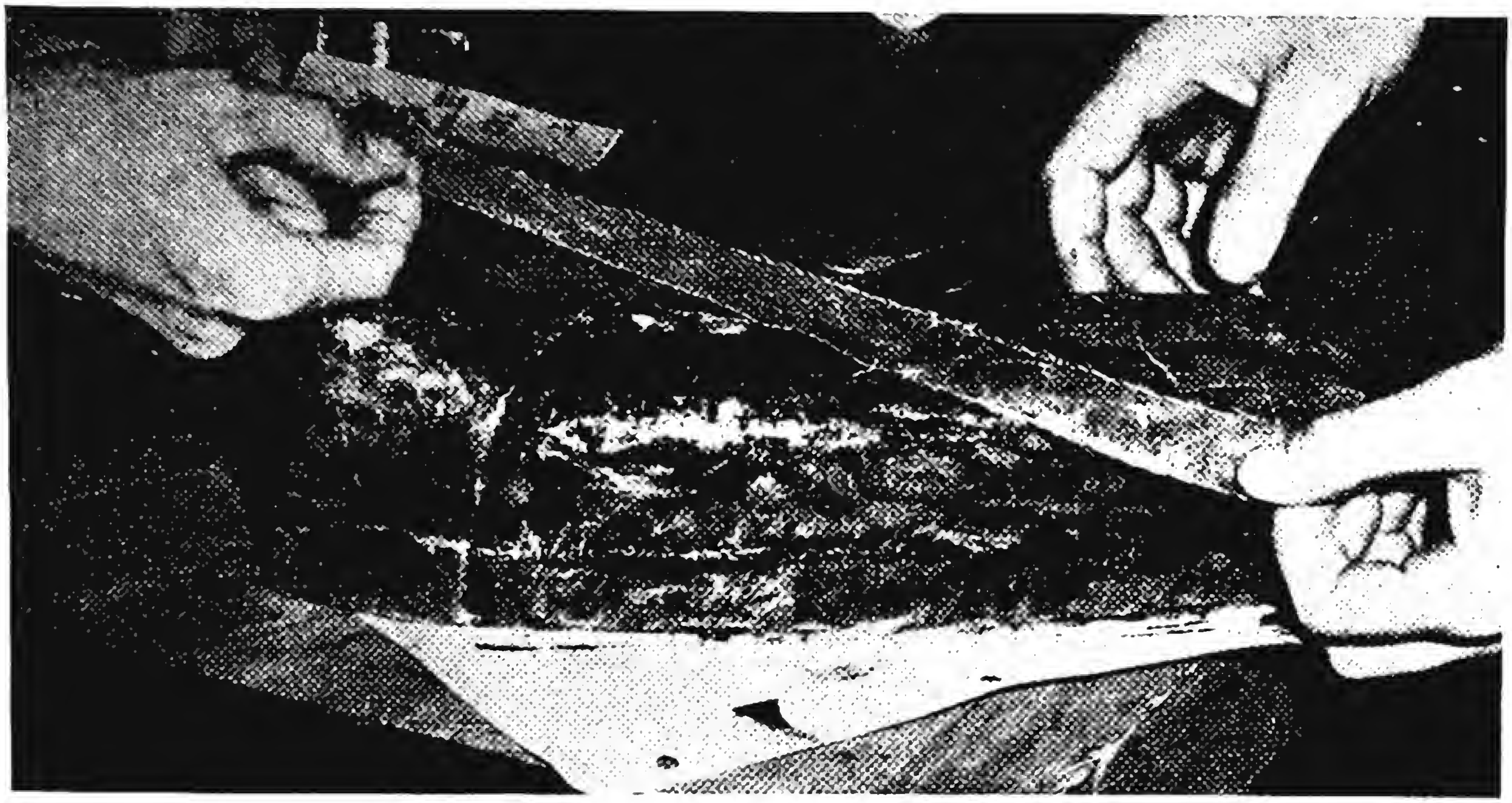

FIGURE 96. Laying up strips of resin-coated cloth on the boat mold.

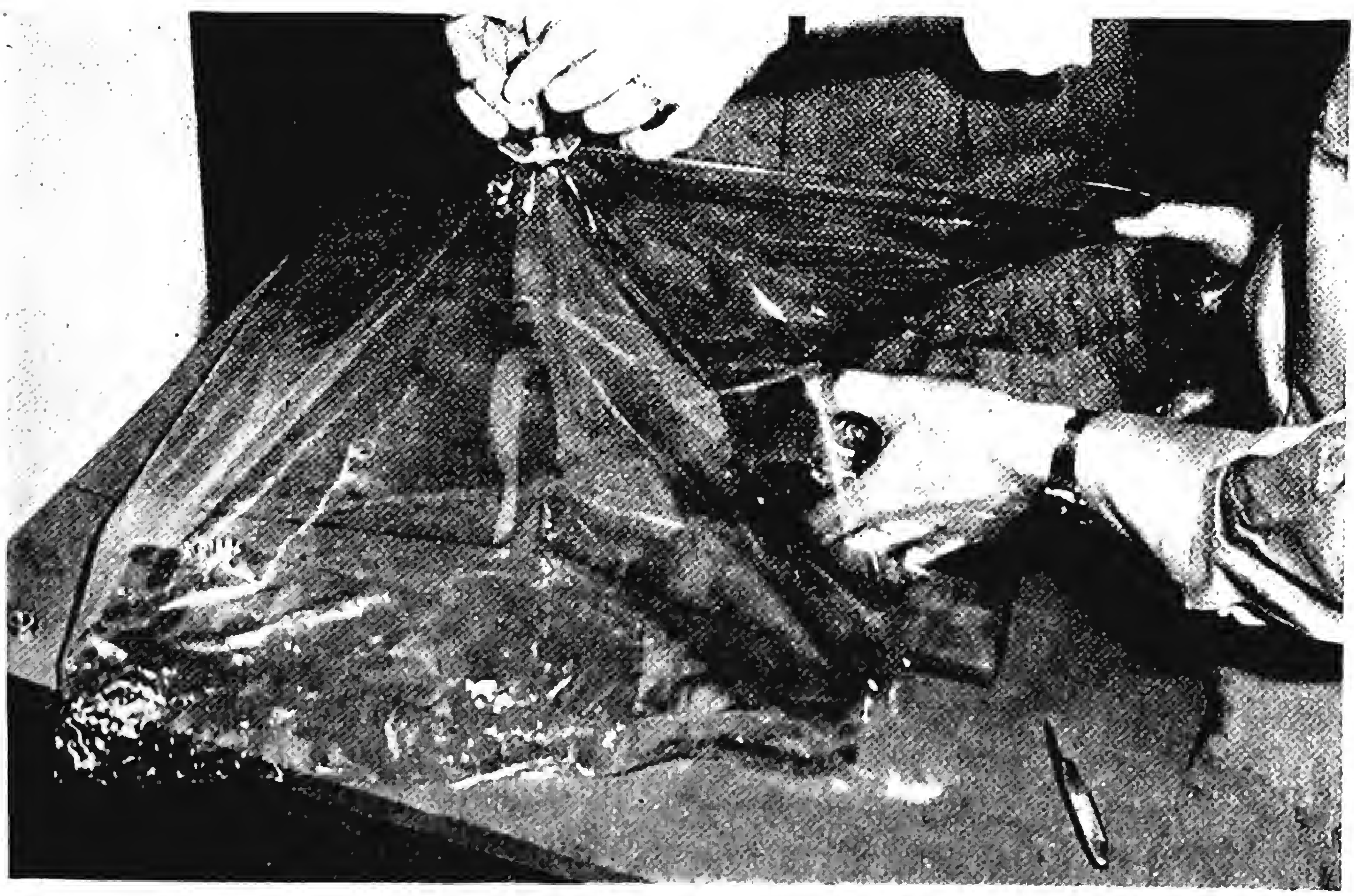

FIGURE 97. Placing the lay-up in the PVA bag preparatory to curing. Note valve stem for connection of vacuum line.

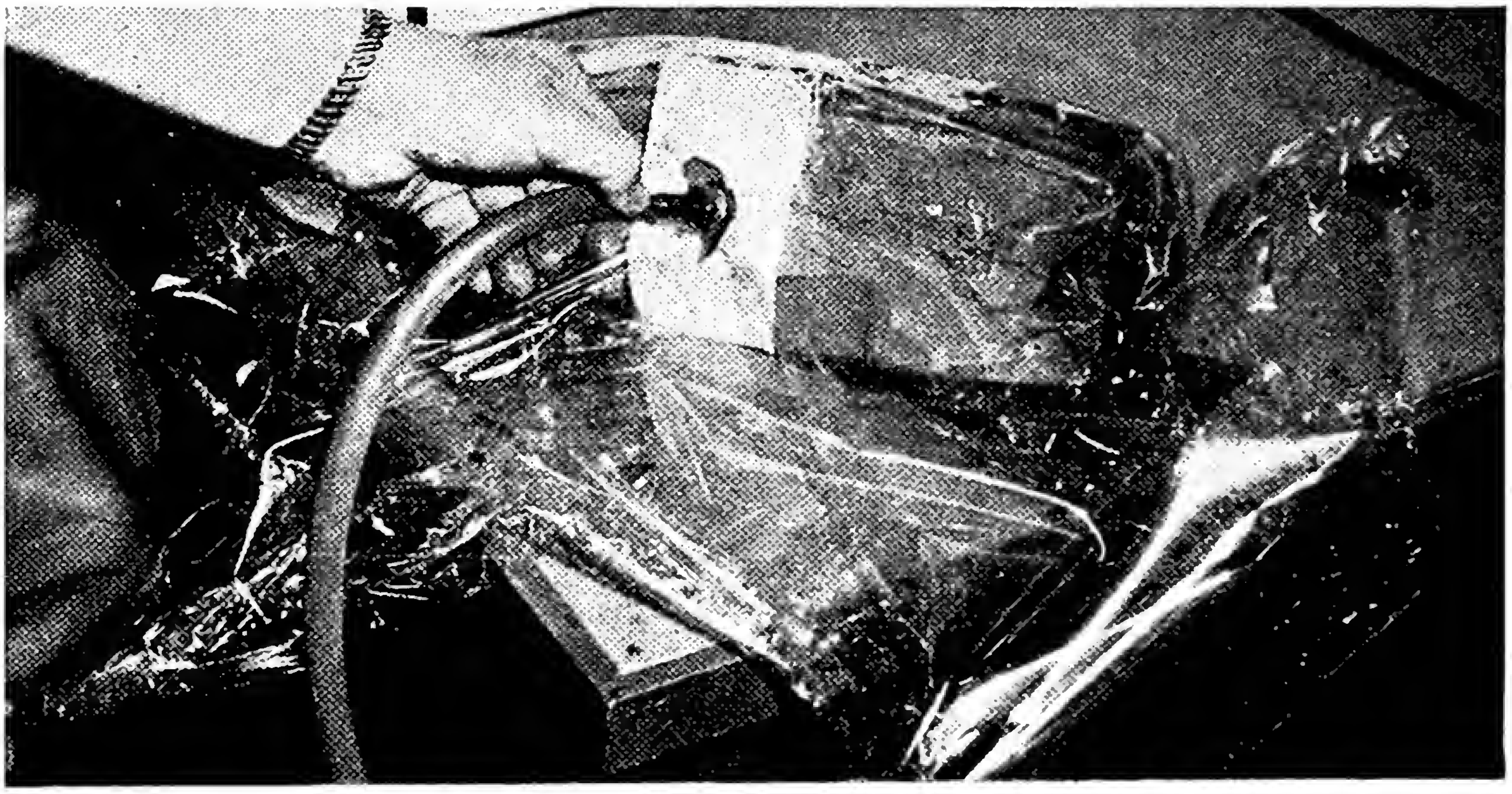

FIGURE 98. Drawing a vacuum on the sealed PVA bag. (*See Figure 91.*)

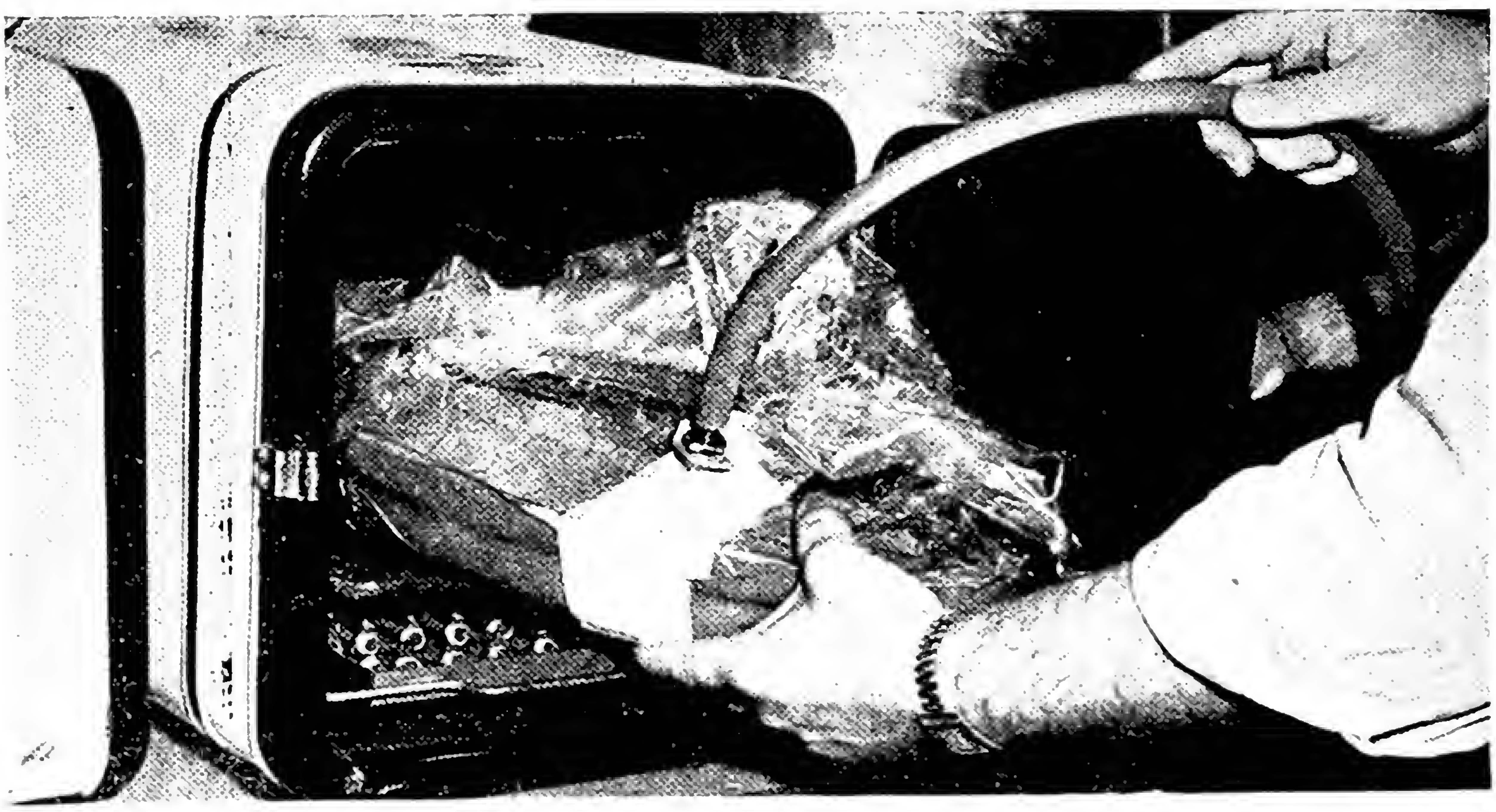

FIGURE 99. Evacuated bag being placed in oven to cure the laminate. Air pressure has collapsed the bag all around.

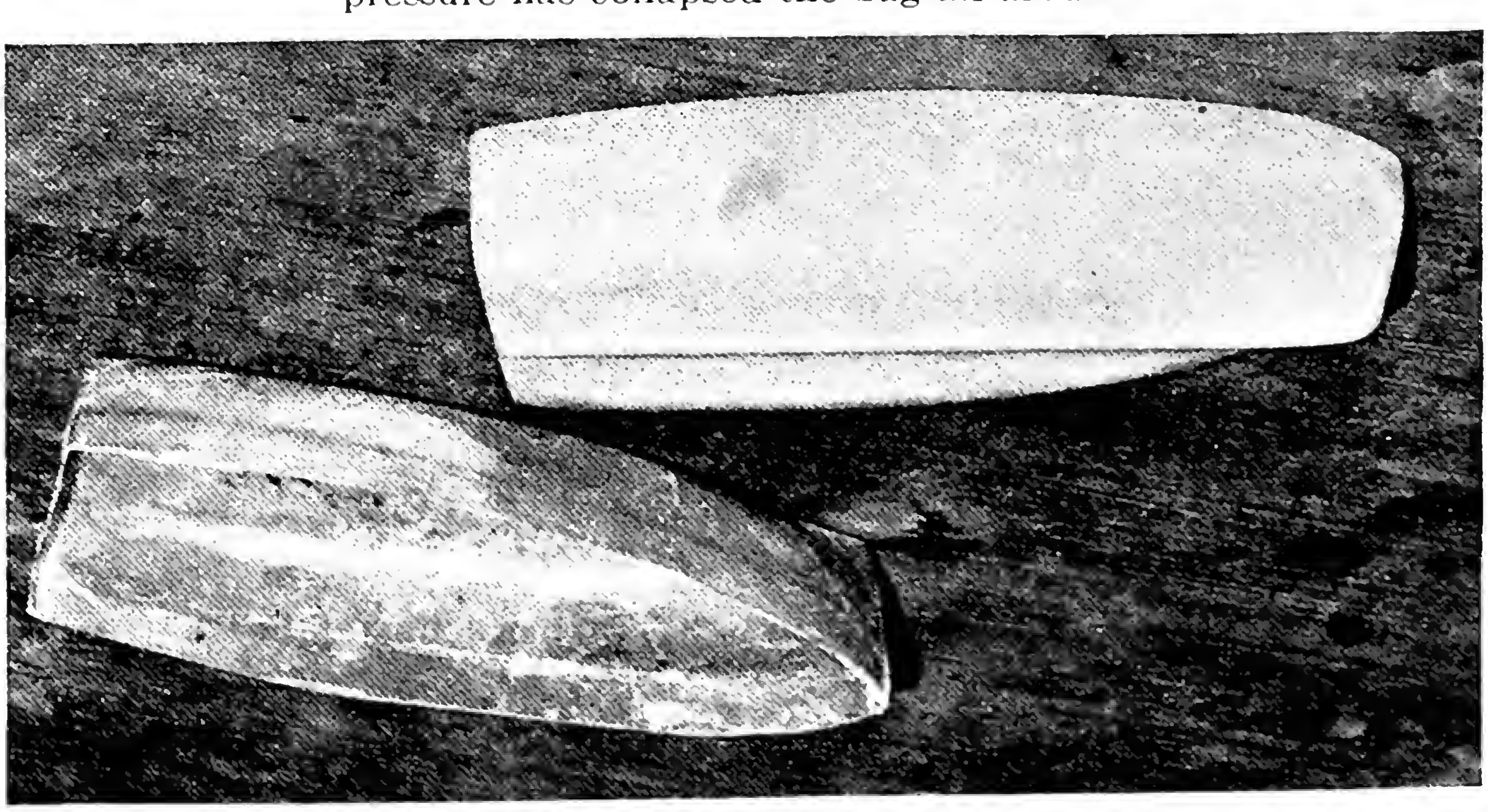

FIGURE 100. Completed boat model, fully cured.

Thermometers to check temperature of 250 to 350 degrees F.
Vacuum pump and storage tank.

Experiment I. Preparation of Coated Cloth

(1) Cut 3 pieces of cloth, each about 6″ x 6″ in size.
(2) Place 3 sheets on a piece of Cellophane about 9″ x 9″ in size.
(3) Mix Selectron 5003 resin and catalyst paste by stirring until a clear solution results. Pour this solution on the center of the cloth sheets and work gently with the blade of a spatula until the cloth is wet. Cover coated cloth with a cellophane sheet. Save this coated cloth for steps 3 and 4 of Experiment III.

Experiment II. Preparation of Coated Mat

(1) Cut a section of mat approximately 6″ x 6″ in size.
(2) Place on a piece of cellophane about 9″ x 9″ in area.
(3) Mix Selectron 5003 resin and catalyst paste by stirring until a clear solution results. Pour this solution on the mat, covering about $\frac{3}{4}$ of the inner area. Spread carefully with the blade of a spatula until the mat is wet with resin. Cover the coated mat with a Cellophane sheet.

Experiment III. Laminated Article From Cloth

(1) Cut out a piece of resin coated cloth approximately 6″ x 18″. Fold over to make into 3 layers with as little wrinkling as possible. Size approximately 6″ x 6″.
(2) Place resin coated cloth between cellophane sheets, about 9″ x 9″ in size.
(3) Check temperature of curing plate. This should be 250° F. to 300° F.
(4) Cure for 3 to 5 minutes on the aluminum mold, using the vacuum self-sealing rubber blanket.

Experiment IV. Laminated Flat Sheet.

Repeat steps 1, 2 and 3 of Experiment III. Cure for 3 to 5 minutes on the Carver press to make a flat sheet. Curing temperature should be 250° F to 300° F.

Experiment V. Machining Plastics

Use flat sheet as made in Experiments IV, VII or VIII for work-bench machining operations. Each class member should do the following:
(a) *Drill* a hole in the sheet.
(b) *Saw* a section of the panel, using a hack-saw.
(c) Sandpaper the rough edges on a piece of the laminate.

Experiment VI. Plastic Ash Tray

(1) Use coated mat prepared in Experiment II.

(2) Follow steps 3 and 4 in Experiment III.

Experiment VII. Fiberglas Mat Flat Sheet

(1) Use mat prepared as in Experiment II for making flat sheet as described in Experiment IV.

Experiment VIII. Heavy Laminated Flat Sheet

(1) Make a flat sheet from 2 or 3 plies of coated mat (Experiment II). Cure for 20 minutes.

(2) Make a flat sheet from 6 to 9 plies of coated cloth (Experiment I). Cure for 20 minutes.

Experiment IX. Colored Plastic Molded Object

(1) Use dye or pigment to color Selectron 5003 resin.

(2) Prepare coated mat as in Experiment II or coated cloth as in Experiment I.

(3) Mold the laminate by curing on aluminum die under vacuum pressure.

Experiment X. Colored Flat Sheet

(1) Repeat 1 and 2 of Experiment IX.

(2) Mold flat sheet on Carver press. Cure at 250° F to 300° F.

Experiment XI. Further Suggestions

(1) Make a laminated plastic boat from a plaster of Paris mold. (See Figures 93 to 100).

(2) Select various objects of wood or metal which are suitable as molds (male or female). Use a parting agent on the mold surface and follow other procedures already described.

Patent Index

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